LAKE TIPPECANOE DIAGNOSTIC STUDY

KOSCIUSKO COUNTY, INDIANA

FINAL REPORT

JUNE 1997

For:

Indiana Department of Natural Resources
Division of Soil Conservation
Lake and River Enhancement Program

and

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LAKE TIPPECANOE DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

A diagnostic study to document the extent of sedimentation, nutrient amplification and contamination within Lake Tippecanoe and its major tributaries was conducted by J. F. New and Associates, Inc and Indiana University - School of Public and Environmental Affairs. The study was funded by the Lake and River Enhancement Program of the Indiana Department of Natural Resources-Division of Soil Conservation and the Lake Tippecanoe Property Owners Association. The study included lake and stream water quality samples, an inventory of aquatic macrophytes, identification of land use patterns, a review of historical studies and recommendations for corrective actions where problems were identified.

Lake Tippecanoe is classified as a mesotrophic lake that has very high inputs of nitrogen and phosphorus. Of 321 Lakes monitored by the Indiana Clean Lakes Program from 1989 to 1993 Lake Tippecanoe ranked 121 in overall tropic state (Jones, 1996). Lake Tippecanoe receives and discharges approximately three times its volume each year via the Tippecanoe River. This frequent turnover has so far prevented an abundant nutrient supply from moving the lake to a eutrophic classification. However, because of this frequent flushing, Lake Tippecanoe is very sensitive to changes in the water quality of Grassy Creek and Tippecanoe River and therefore to watershed land use activities and runoff characteristics. Oxygen is currently adequate in the upper 16 feet (5 m.) of the lake. Below this depth, photosynthesis does not occur to produce additional oxygen and most of the available oxygen is consumed by respiring zooplankton. The resulting low oxygen levels limit the fisheries potential of the lake. Additionally, anoxic conditions near the bottom continually recycles the settling phosphorus back into the water column as sediments are disturbed by power boat activity. Streams contributing the most nutrients and suspended sediments to the lake in decreasing order of importance are Grassy Creek, Tippecanoe River including Kuhn Ditch, Hannabe-Walker Ditch and Indian Creek. Eurasian milfoil was the only common macrophyte species found to be detrimental to recreational use of the lake. Milfoil is found predominantly in Oswego lake at the western end of Lake Tippecanoe. Eurasian milfoil can be controlled with annual spot treatments of a herbicide such as Aqua-Kleen or an equivalent early emergent systemic treatment.

Reducing the nutrient loading by 20% is critical to maintaining the mesotrophic condition of Lake Tippecanoe. Since there are many sources of these nutrients, several methods need to be applied to reduce both short term and long term loading. While the size of the Tippecanoe River and Grassy Creek prohibit in-stream treatment, conservation practices administered by the Soil and Water Conservation District offices in the upper reaches of the watershed will have significant long term potential to reduce nutrients. Support of their programs by lake residents is crucial. Suspended sediments and nutrients can be reduced on each of the smaller tributaries by constructing storm water detention structures, wetland filters, or sediment traps within the existing ditch right-of-way. Several conceptual designs and cost estimates are included with this report. As importantly, obeying no-wake boating regulations within shallow areas of Lake James, Lake Tippecanoe and Oswego Lake will reduce the resuspension of nutrient laden sediments on the lake bottom. Dredging at the mouth of Hannabe-Walker Ditch and Indian Creek will reduce the amount of sediment exposed to power boat activity and decrease the amount of nutrients available to the water column, however, dredging is only recommended after sediment sources have been reduced. Finally, developing a sewage treatment system for all residential and commercial establishments within 500 feet (150 m.) of the lake should be an immediate priority for landowners and users of the Lake Tippecanoe system.

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KOSCIUSKO COUNTY, INDIANA

I. INTRODUCTION

Lake Tippecanoe, including Lake James and Oswego Lake, is a 1,133 acre (459 ha) glacial lake located in Kosciusko County, 4.5 miles (7.2 km) east of Leesburg, Indiana (Figure 1). The lake is located downstream from the Barbee Lake Chain on Grassy Creek and downstream of Webster Lake on the Tippecanoe River. The Tippecanoe River flows into the Wabash River in Lafayette, Indiana. The Wabash is a tributary of the Ohio River. Lake Tippecanoe is the deepest natural lake in Indiana with a maximum depth of 123 feet (38 m) and an average depth of 37 feet (11 m). The water level of the lake is maintained by a dam at the west end of Oswego Lake (IDNR, 1995). Lake Tippecanoe has a volume of 28,491 acre-feet or 142,566 cubic m^3 (U.S. EPA, 1976). The three basins have a total volume of 35,230 acre-feet or 115,295 cubic m^3 and their combined hydraulic retention time is 4.5 months.

Lake Tippecanoe's watershed covers 112 square miles (290 km^2) in Kosciusko, Noble and Whitley Counties (Figure 2). This relatively large watershed area results in a watershed-to-lake ratio of 93.1. Thirty-three percent of the watershed contains highly erodible soils (Hippensteel, 1989). Agriculture accounts for approximately 50% of the land use and is primarily cropland (90%) with smaller areas of pasture (10%) (U.S.D.A., 1993). Field reconnaissance and an analysis of aerial photos suggests that much of the highly erodible soil is enrolled in Conservation Reserve or set aside and grassed waterways are used extensively. The 1996 tillage data show that on average 50% of the active agricultural land is now in soil management programs including mulching and no till (USDA Kosciusko County staff, personal communication).

The mean total phosphorus concentration in Lake Tippecanoe has risen from 20μg/L in 1973 (U.S. EPA, 1976) to 50μg/L in 1989 (IDEM, 1989) and to 69.5 μg/L in 1994 (IDEM, 1994). Likewise, the mean summer Secchi disk transparency has decreased from 23 feet (7.1 m) in 1992 to 17.6 feet (5.36 m) in 1994 (Jones, et al., 1994, IDEM, 1994). These results suggest a trend of increasing eutrophy in the lake. The trophic index for Lake Tippecanoe currently ranges from 12 to 24 but within Lake James reaches 40 (IDNR, 1995).

Approximately 90% of the lake's 6.2 mile (10 km) shoreline is residential, and the remaining 10% is privately owned wetlands (Andrews, 1982). A total of 1089 homes and 210 mobile homes (total =1299 dwellings) are situated within the residential area (Bonar and Associates, 1995). According to Lake Tippecanoe residents, the biggest lake problems are sedimentation of channels and poor water clarity. Excessive algal and rooted macrophyte populations have also been cited as problems in some channels.

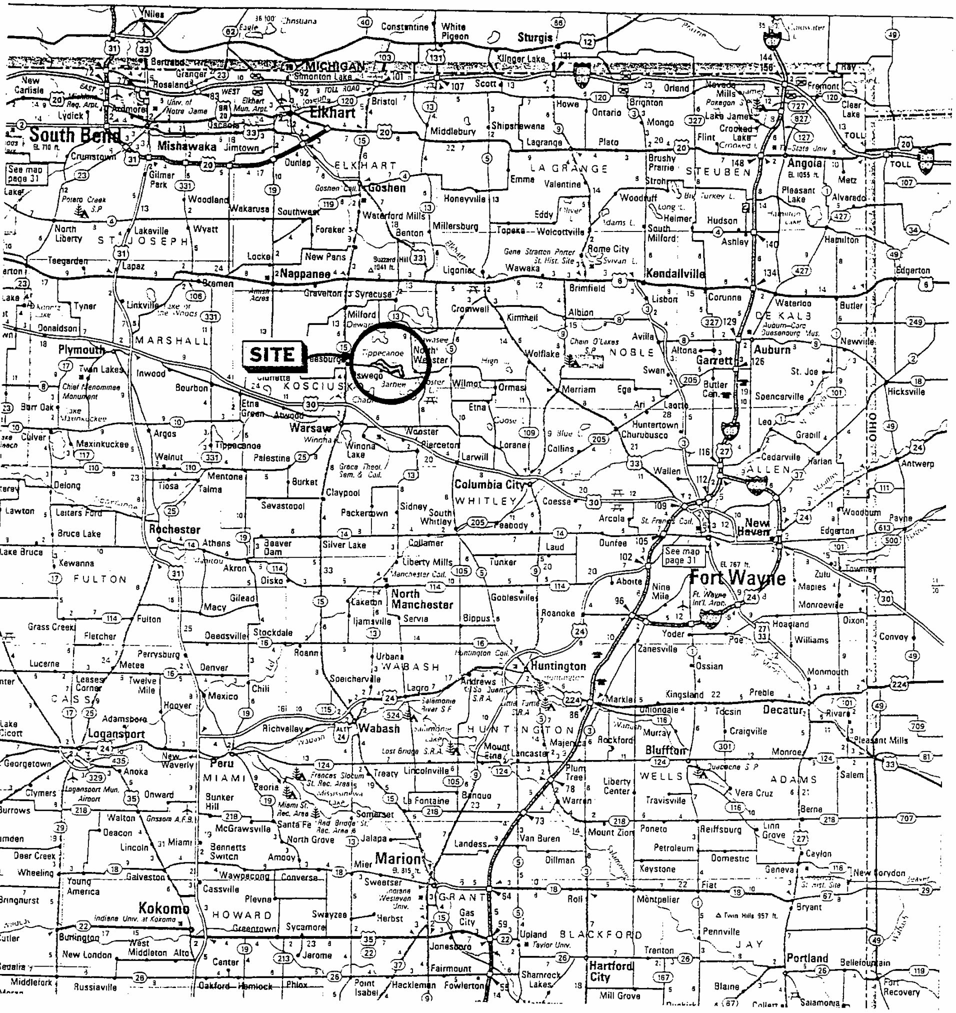

FIGURE 1.
LAKE TIPPECANOE FEASIBILITY STUDY

LOCATION MAP

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Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
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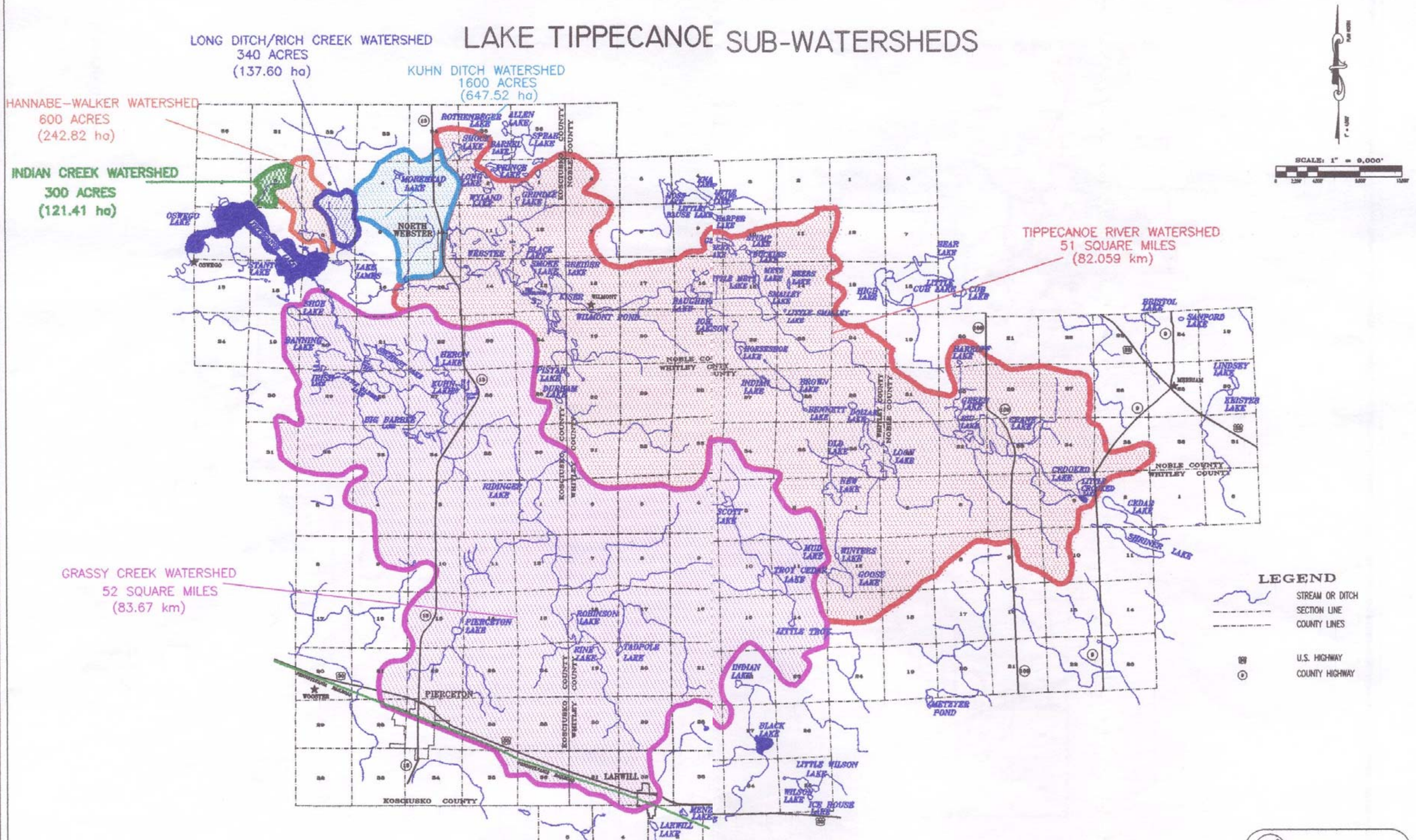

FIGURE 2.
SUBWATERSHED BOUNDARY MAP
LAKE TIPPECANOE FEASIBILITY STUDY

In response to the scope of work requested by the Lake Tippecanoe Property Owners, Inc. through its T-By-2000 diagnostic grant, the team of J.F. New and Associates, Inc. and the Indiana University School of Public and Environmental Affairs has concentrated on identifying sediment and nutrient sources that affect the water clarity and health of the lake. The study reviewed the historical conditions, collected and analyzed sediment, vegetation and water samples to document existing conditions and has proposed implementable and cost effective solutions to resolve the problems identified.

II. IDNR FISHERIES REPORTS

To assess the current status and possible future trends of the Lake Tippecanoe fishery, two IDNR Fish Management Reports from the years 1982 and 1995 are reviewed and summarized in this section. Generally, overall conditions of the lake as described by the 1995 IDNR report are similar to the 1982 report. Areas of natural shoreline are few and submergent and emergent plants are lacking due to the sharp contour and bottom material of the lake. Oxygen levels in the top 15-20 feet (4-6 m) of the lake are sufficient for the survival of fish in the summer (IDNR 1995), however, below that level conditions become anoxic. In addition, the bottom substrate of the lake provides little habitat for fish and is composed of muck, sand and marl.

According to the 1982 report, Lake Tippecanoe contained mostly deep areas with limited littoral areas, while the shallower Lake James contained a much greater percentage of littoral zone. Fish travel freely between the two lakes. In 1982, native aquatic vegetation was limited primarily to boat channels and the undeveloped eastern shoreline. The 1995 report cites earlier reports of abundant vegetation (Miles, 1915), while stating that an overall lack of vegetation currently provides poor habitat for fish.

The 1982 IDNR report indicates that fish populations in the lake were diverse and stable with an abundance of non-game species (Table 1). Game fishing stocks were satisfactory to very good including (listed in order from most abundant to least), yellow perch (*Perca flavescens*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*) and white bass (*Morone chrysops*). The 1995 IDNR electrofishing survey revealed only slightly different results (Table 1). Bluegills dominated the total catch by number, followed by gizzard shad (*Dorosoma cepedianum*) (4.2% of the overall catch in 1982, 29% in 1995) and largemouth bass (8.3% in 1982, 9% in 1995). Overall, the fish community is diverse and numbers of non-game species are high. The diversity of species collected in the survey was typical for lakes connected to large river systems, although the deep areas of the lake were deemed "mostly unproductive for fish" in the report. The deep open water areas once sustained healthy populations of cisco (*Coregonus sp.*) while the 1982 and 1995 surveys revealed no cisco. According to the reports, degradation of water quality led to extinction of cisco in the 1970's within Lake Tippecanoe.

Management of the fishery included stocking of walleyes in 1975, 1977 and from 1982 until 1986 and implementation of a 12 inch (30 cm) minimum size limit on largemouth bass in 1990. The walleye and largemouth bass densities were lower than similar lakes and it was believed to be due to the low natural fertility of Lake Tippecanoe. No reintroductions of cisco were recommended until water clarity is improved.

The surveys suggest that plankton eating fishes such as gizzard shad will continue to increase with the documented increase in nutrient loading. Some game fish populations, such as northern pike and largemouth bass should increase due to the increased forage fish population. Walleye and cisco, which require more oligotrophic conditions, will not return to a fishable population until the nutrients and thus the algal population is controlled.

Table 1. Number of fish collected during fish population surveys at Lake Tippecanoe from 1976-95, IDNR Fish Management Report (1995).

		Number	
Species	1976	1982	1995
Bluegill	655	166	295
Bullhead	32	68	7
Catfish	22	29	40
Crappies	70	69	9
Perch	145	186	31
Redear	76	32	4
White Bass	9	18	12
Other sunfish	155	18	30
LM Bass	131	75	74
SM Bass	11	5	3
Carp	9	3	2
Gar	50	1	12
Shad	384	37	244
Suckers	76	107	28
Others	227	58	25
Total	2,051	887	837

III. AQUATIC VEGETATION SURVEY

Lake Tippecanoe, Oswego Lake and Lake James were surveyed for macrophyte bed coverage and species composition in the spring and summer of 1996. Based on the survey of aquatic beds, an outline for management of aquatic plant resources is recommended.

Aquatic plants are a beneficial and necessary part of healthy lakes and ponds. Their role is important because plants can directly convert solar energy into stored chemical energy for use by animals, while at the same time, remove excess nutrients from the surrounding water and sediments. Just as important is the fact that microscopic plants produce the majority of dissolved oxygen in water for use by aquatic animals. Plants stabilize shorelines with their roots and by acting as wave breakers, and many produce flowers or unique leaf patterns which are aesthetically attractive.

Emergent aquatic plants such as cattail and bulrush are used by beneficial insects, terrestrial birds, amphibians, shorebirds and waterfowl. Patches of emerged plants are extremely important for shelter, brooding, and feeding areas. Ideally, for breeding waterfowl, clumps of emergent vegetation should cover about ½ of the lake's shoreline area. In addition, waterfowl use aquatic plants, such as pondweed, coontail, duckweed, water milfoil, and arrowhead for food. Aquatic plants also serve as escape areas for young fishes ensuring that some survive and mature to produce additional young.

Within the lakes, 13 macrophyte beds were found. The lakes were surveyed in both spring and summer. Some beds were found during both surveys, while other beds only appeared during one of the surveys. An association of species including natives and non-natives was found in these beds. Figures 3 and 4 identify the location of the beds and the occurrence of non-native species in the entire lake system. A list of species in each bed is found in Table 2. Lake James was found to have the most diverse plant beds with scattered occurrences of non-native species. Conversely, Oswego Lake was almost completely dominated by the non-native, Eurasian milfoil, with little native aquatic plant diversity. Lake Tippecanoe, the largest of the three, had more incidence of scattered plant beds including native and non-native species.

Twenty species were found during the spring inspection. In the summer inspection, 27 species were found. In addition, during the summer inspection, there were less beds dominated by Eurasian milfoil. The difference in bed location and composition from the spring to the summer inspection may be due to several factors. Seasonal changes including photoperiod and temperature have an effect on when certain aquatic plants begin to grow. The absence of Eurasian milfoil dominated beds (especially in the west end of the lakes) during the summer is explained by chemical treatment for milfoil between the two sampling dates.

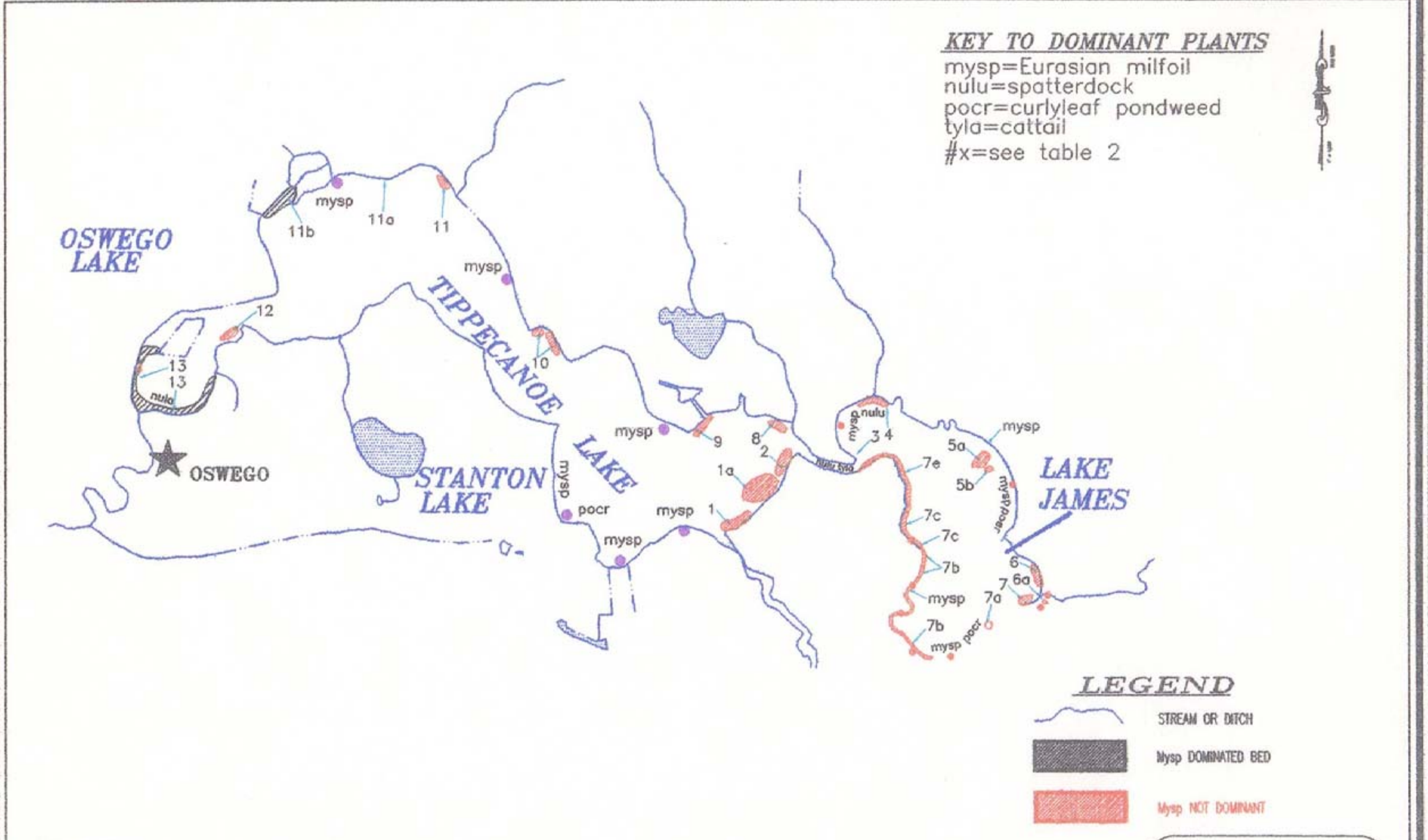

FIGURE 3.
LAKE TIPPECANOE-KOSCIUSKO COUNTY, INDIANA
SPRING MACROPHYTE SURVEY

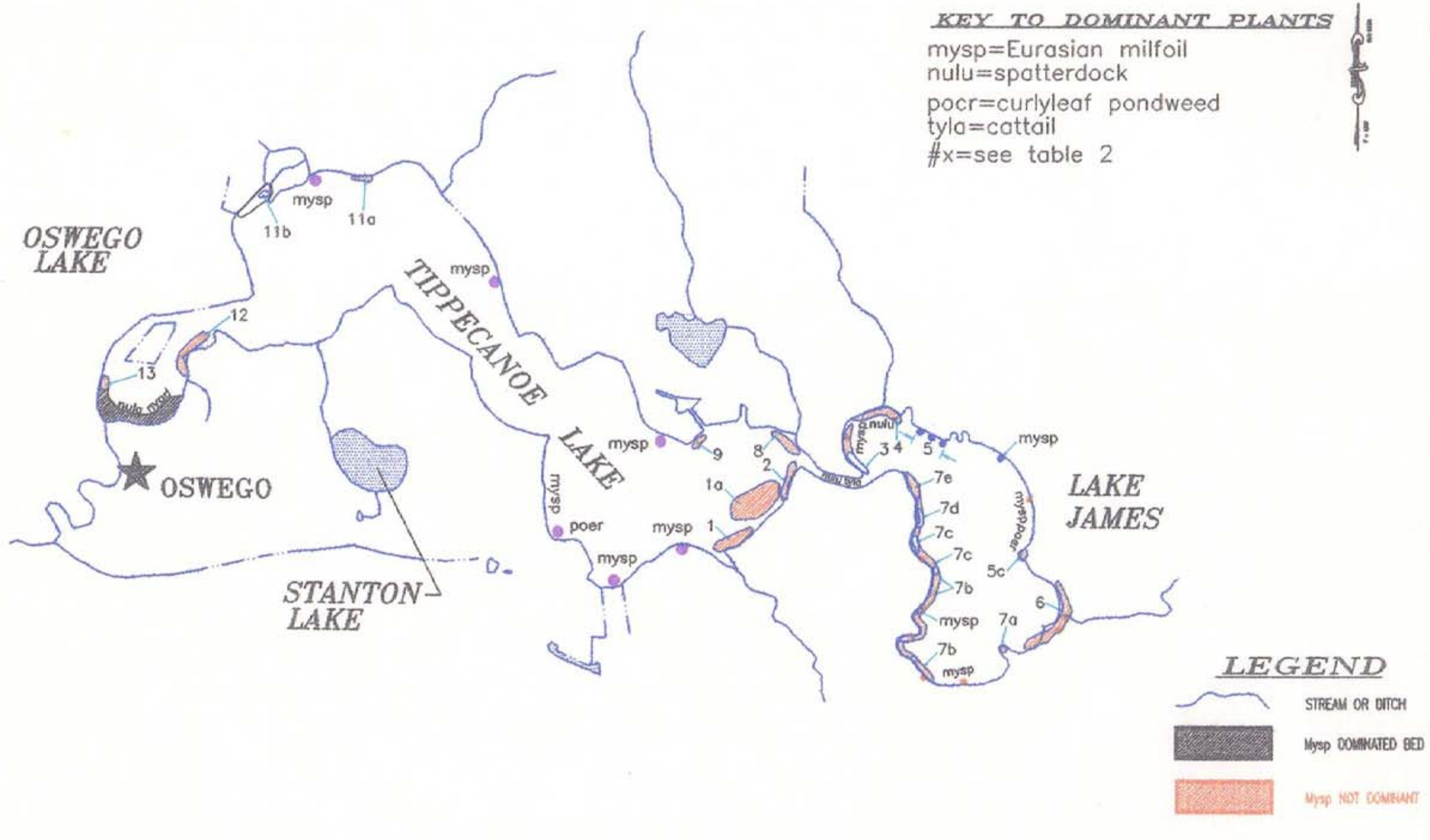

FIGURE 4.
LAKE TIPPECANOE-KOSCIUSKO COUNTY, INDIANA
SUMMER MACROPHYTE SURVEY

J.F. New & Associates, Inc.

Overall, 29 native aquatic species (including submerged, floating-leaved and emergent) were found in the lakes. Two non-native species were also found, Eurasian milfoil (*Myriophyllum spicatum*) and curly leaf pondweed (*Potamogeton crispus*). Of these, Eurasian milfoil is more common and completely dominates some of the plant beds.

The species list was analyzed using the Floristic Quality Assessment (Swink & Wilhelm 1994) as developed for the Chicago Region and implemented in other states such as Michigan and Missouri. This assessment rates species based on their likelihood of existing in an intact natural community. The Lake Tippecanoe rates rather high with a Floristic Quality Assessment (FQI) value of 30.72. Generally, a site with a FQI value of 35 or higher is at least of marginal natural area quality. A site that rates with a high FQI value is beneficial to the overall health of the system, in this case the entire Tippecanoe Lake complex. The Ball Wetlands Nature Preserve managed by the Indiana Department of Natural Resources Nature Preserve is located in Lake James and the northeast end of Lake Tippecanoe. The presence of the nature preserve has decreased development on that portion of the shoreline and provided habitat to sustain unique aquatic vegetation. One way to increase the likelihood of a diverse group of native aquatic plants is to focus on management of exotic species such as Eurasian milfoil.

The summer inventory provided a slightly higher FQI value than the spring. This may be due to the fact that July is the time of year that the majority of aquatic plants are easiest to identify. Another possibility may be that the lake was chemically treated in June to control Eurasian milfoil. Once milfoil was temporarily eliminated from certain areas, native species were given advantages including more available sunlight to expand their population.

MANAGEMENT RECOMMENDATIONS

Dense, monotypic macrophyte beds, especially beds composed of Eurasian milfoil have limited habitat value and interfere with boat navigation. Although a small percentage of Tippecanoe Lake's surface area is covered with macrophytes, the dense beds can cause localized problems and some selected control in these small areas is likely warranted. Complete elimination of plants in lakes and ponds is not recommended. Rather, strips of aquatic plants should be left in areas where recreation will not be inhibited. There are several options lake front owners have when control of aquatic plants is necessary. Options include mechanical harvesting, temporary drawdown of the lake water levels, bottom shading and chemical control.

In Lake Tippecanoe, the primary aquatic weed problem is Eurasian milfoil. Eurasian milfoil is an exotic species, non-native to the United States. Most exotic species have little or no wildlife value and can often eliminate desirable native species due to competition for available resources and the lack of natural predators. Eurasian milfoil has the ability to grow two inches per day and also grow from fragments.

Mechanical Harvesting-
Although macrophyte harvesting is not a long-term restoration method, it can manage the growth of aquatic macrophytes and give lake users immediate access to areas and activities that have been affected by excessive macrophyte growth. Plants harvested several times during the growing season, especially late in the season, often grow more slowly the following season (Cooke et al., 1993). Further benefits are derived if the cut plants and the nutrients they contain are removed from the lake. Harvested vegetation that is cut and left in the lake ultimately decomposes, contributing nutrients and consuming oxygen. Many harvested plants, especially milfoil, can re-root or reproduce vegetatively from the cut pieces left in the water.

Algal blooms following harvesting have been reported in some lakes because the rooted plants no longer compete with the algae for available nutrients. Mechanical harvesting costs using large harvesting vessels vary according to capital cost and capacity of the harvester, amortization rate, amount of time required to unload harvested material, size of lake, and other factors. Depending upon the specific situation, harvesting costs can range up to $4000 per acre ($1600 per hectare, Prodan 1983, Adams 1983). Estimated costs of the mechanical harvesting program at Lake Lemon (Bloomington, Indiana) averaged $1630/acre ($659/ha, Zogorski et al., 1986). Hand harvesting equipment is available for smaller areas around piers at a cost of from $50-$1500.00 (McComas, 1993).

Chemical control -
Since Eurasian milfoil can grow by fragmentation, mechanical harvesting is not a recommended option because harvesting will spread the problem. The best alternative according to Jim Donahue of <u>Aquatic Weed Control</u>, in Syracuse Indiana, is using a root control herbicide such as Aqua-Kleen, which is a granular ester formulaton of 2,4-D (an early emergent systemic herbicide. The advantages of 2,4-D is that it can be used to spot treat milfoil patches versus other chemical compounds which may require the entire lake to be treated for effectiveness. Aqua-Kleen is most effective when the plants are actively growing in the spring. The Eurasian milfoil in Lake Tippecanoe is dominant in the south and southwest end, and patchy throughout the rest of the lake.

Drawdown -
Temporary drawdown of water levels is another alternative macrophyte control. Control is achieved by destroying seeds and vegetative reproductive structures (e.g. tubers, rhizomes) via exposure to drying or freezing conditions. To do so, complete dewatering and consolidation of sediments is necessary. Dewatering may not be possible in seepage lakes. As a macrophyte control technique, drawdown is recommended in situations where prolonged dewatering of sediments is possible under conditions of severe heat or cold and where susceptible species are the major nuisances. Eurasian milfoil control, for example, apparently requires three weeks or longer of dewatering prior to a one-month freezing period for effective control (Cooke, 1980). Some resistant species can experience a growth surge after a successful drawdown operation.

There are a number of other benefits to lakes and reservoirs from drawdown. Game fishing often improves after a drawdown because it forces smaller fish out of the shallow areas and concentrates them with the predators. This decreases the probability of stunted fish and increases the winter growth of the larger game fish. Drawdown has also been used to consolidate loose, flocculent sediments that can be a source of turbidity in lakes. Dewatering compacts the sediments and they remain compacted after reflooding (Born et al., 1973 and Fox et al., 1977). Lake level drawdown is an attractive restoration technique due to its low cost. Lake Tippecanoe is a potential candidate for the use of draw down to control milfoil.

Bottom shading -
Bottom shading by covering bottom sediments with fiberglass or plastic sheeting materials provides a physical barrier to macrophyte growth. Buoyancy and permeability are key characteristics of the various sheeting materials. Buoyant materials (polyethylene and polypropylene) are generally more difficult to apply and must be weighted down. Sand or gravel anchors can act a substrate for new macrophyte growth, however. Materials must be permeable to allow gases to escape from the sediments; gas escape holes must be cut in impermeable liners. Commercially available sheets made of fiberglass-coated screen, coated polypropylene, and synthetic rubber are non-buoyant and allow gases to escape, but cost more (up to $66,000 per acre or $27,000 per hectare for materials, Cooke et al., 1993). Indiana regulations specifically prohibit the use of impermeable material for plant control or as a base for beaches.

Due to the prohibitive cost of the sheeting materials, sediment covering is recommended for only small portions of lakes, such as around docks, beaches, or boat mooring areas. This technique may be ineffective in areas of high sedimentation, since sedimentt accumulated on the sheeting material provides an area for macrophyte growth. The IDNR requires a permit for any permanent structure on the lake bottom, including anchored sheeting.

SUMMARY

Aquatic macrophytes in Lake Tippecanoe, Lake James, and Oswego Lake are not over abundant. Thirteen patches or beds of macrophytes were found with a high diversity of native plants. The only problem observed is the control of the exotic species, Eurasian milfoil. Milfoil is best treated by lake draw downs or annual spot treatment with the chemical Aquakleen. The goal at Lake Tippecanoe should be for selective aquatic plant management rather than eradication. Dense macrophyte beds can have lanes cut through them to improve fishing access and to allow predator fish access to forage fish deep in the beds. Where macrophytes are a problem around docks, piers, boat landings and beaches, they can be controlled easily by hand harvesting with one of the available hand cutters designed specifically for aquatic plants. Beds of native macrophytes should be encouraged in areas where they do not inhibit recreation to provide fish habitat and other benefits.

Table 2. Lake Tippecanoe Macrophyte and Aquatic Plant Survey
May 30, 1996 and July 31, 1996

CODE	SCIENTIFIC NAME	COMMON NAME
Asin	*Asclepias incarnata*	Swamp milkweed
Cede	*Ceratophyllum demersum*	Coontail
Ceoc	*Cephalanthus occidentalis*	Buttonbush
Ch	*Chara sp.*	Muskgrass/stonewort
Deve	*Decodon verticillatus*	Swamp loosestrife
Elca	*Elodea canadensis*	Waterweed
Hedu	*Heteranthera dubia*	Water star grass
Himi	*Hibiscus militaris*	Halbered leaved rose mallow
Lemi	*Lemna species (minor)*	Duckweed
My	*Myriophyllum sp.*	Water milfoil
Mysp	*Myriophyllum spicatum*	Eurasian milfoil
Nafl	*Najas flexilis*	Slender naiad
Nulu	*Nuphar luteum*	Spatterdock
Nytu	*Nymphaea tuberosa*	White water lily
Pevi	*Peltandra virginica*	Arrow arum
Po	*Potamogeton sp.*	Pondweed
Poam	*Potamogeton amphlifolius*	Large leaf pondweed
Poco	*Pontedaria cordata*	Pickerel weed
Pocr	*Potamogeton crispus*	Curlyleaf pondweed
Pofo	*Potamogeton foliosus*	Leafy pondweed
Pogr	*Potamogeton gramineus*	Grass-leaved pondweed
Pope	*Potamogeton pectinatus*	Sago pondweed
Popr	*Potamogeton praelongus*	White stemmed pondweed
Popu	*Potamogeton pusillus*	Slender pondweed
Pozo	*Potamogeton zosteriformis*	Flat stem pondweed
Sc	*Scirpus sp.*	Bulrush
Scva	*Scirpus validus*	Soft stem bulrush
Tyla	*Typha latifolia*	Broadleaf cattail
Utvu	*Utricularia vulgaris*	Great bladderwort
Vaam	*Vallisneria americana*	Eelgrass/water celery
Zapa	*Zannechellia palustris*	Horned pondweed

Bed Number	Approximate Size May 30, 1996	July 31, 1996	Species Found
1	100' X 25'		Cede*, Mysp*, Nafl, Nulu*, Pocr, Popu*, Utvu, Zapa
		500' X 100'	Cede, Ch, My, Mysp*, Nafl, Nulu*, Pogr, Pope, Pozo, Utvu
1a	250' x 75'		Ced, Filamentous algae, Mysp*
		200' x 70'	Filamentous algae, Mysp
2	75' x 25'		Mysp, Popu
		50' x 25'	Ch, Le, Nafl, Pogr, Pope, Popu, Utvu, Vaam
3	150' x 20'		My Nulu*, Nytu, Poam, Pocr
		500' x 30'	Nafl, Nulu*, Nytu, Pevi, Poam, Pocr, Pogr, Popr, Poco, Pozo
4	100' x 12'		Mysp*, Nulu, Nytu, Pocr
		700' x 100'	Cede*, Le, Mysp*, Nafl*, Poam*, Pope, Pozo, Vaam, Hedu
5	Scattered		Elca, Pocr, Popr
		Scattered Shoreline	Mysp, Nafl*, Nulu, Pevi, Poco, Pozo, Sc, Tyla, Vaam
5a	75' x 50'		Mysp
5b	50' x 20'		Mysp
5c		Shoreline	Scva
6	50' x 25'		Ch, Elca, Mysp
		200' x 50'	Ch*, Elca*, My, Mysp, Nafl, Pope, Pozo*, Utvu, Vaam, Nulu
6a	125' x 50'		Nulu Stream inlet: Cede, Mysp, Pogr, Utvu, Vaam
7	75' x 60'		Cede, Elca, Mysp, Pocr, Popu
7a	20' x 5'		Ceoc, Deve
		20' x 10'	Ceoc, Deve, Sc
7b	Scattered		Mysp, Nulu, Nytu, Pocr, Sc, Tyla

Bed Number	Approximate Size May 30, 1996	Approximate Size July 31, 1996	Dominant Plants
7b		Scattered	Asin, Ceoc, Himi, Nulu, Nytu, Peco, Pevi, Poco, Sc, Ty. Clumps of Mysp
7c	Scattered		Mysp, Nulu*
		50' x 20'	Nafl, Pogr, Pope, Pozo
7d		50' x 10'	Sc
7e		150' x 75'	Mysp
8	50' x 25'		Cede, Mysp, Poam, Pocr, Popu
		500' x 150'	Algae, Cede, Mysp, Pozo, Vaam
9	25' x 10'		Nulu, Mysp, Po, Popu
		200' x 90'	My, Mysp, Nulu, Pogr, Popu Nafl
10	90' x 10'		Mysp, Pocr, Popu
11	50' x 50'		Mysp, Pocr, Pozo
11a		10' x 5'	Pogr, Pope
11b	Entire cove		Mysp*, Nulu
		10' x 10'	Nulu, Ponu
12	50' x 20'		Nulu
		70' x 10'	Nulu*, Nytu
13	Shoreline		Mysp
		25' x 50'	Mysp*, Nafl, Nulu

* Denotes most dominant plants.

IV. LAKE WATER QUALITY SAMPLING

METHODS

Water samples were collected on August 14, 1996 from sites over the deepest area of Lake Tippecanoe and Lake James, and from the channel connecting the two lakes (Figure 5). At each lake site, we collected water samples or measured the following parameters at one and one-half feet (0.5 m) below the surface (epilimnion) and one and one-half feet (0.5 m) off the bottom (hypolimnion):

- pH
- alkalinity
- conductivity
- total phosphorus (Total Phos.)
- soluble reactive phosphorus (SER)
- nitrate+nitrite (NO_3)
- ammonia (NH_4)
- total organic nitrogen (org-N)
- suspended solids

Conductivity was measured *in situ* with a YSI Model 33 S-C-T Meter. The remaining samples were placed into an appropriate bottle with preservative (if needed) and stored in an ice chest until analysis in the laboratory. Temperature and dissolved oxygen were measured *in situ* with a YSI Model 54A Dissolved Oxygen Meter at one-meter intervals from the surface to the bottom. At each lake site, the following additional collections or measurements were made:

- Secchi disk transparency
- light transmission at three feet (Beckman Enviroeye)
- determination of the one percent light level (Beckman Enviroeye)
- chlorophyll a (in epilimnion only; filtered in the field and stored on ice)
- plankton genera biomass (tow from the 1% light level with a 55 micron net)

The same parameters were determined at only the 3.2 foot (1 m) depth at the channel connecting lakes Tippecanoe and James due to the shallow depth of the channel.

RESULTS

Lake Tippecanoe

Temperature and oxygen profiles for Lake Tippecanoe show that the lake was stratified at the time of sampling (Figure 6). During thermal stratification, the bottom waters (*hypolimnion*) of the lake are isolated from the well-mixed surface waters (*epilimnion*) by temperature-induced density differences. The boundary between these two zones, where temperature changes most rapidly with depth is called the *metalimnion*. At the time of our sampling, the epilimnion was confined to the upper 13 feet (4 m) of water. The sharp decline in temperature between 13 feet and 40 feet (4-12 m) defines the metalimnion or transition zone. The hypolimnion occupied water deeper than 40 feet (12 m). Lake Tippecanoe has an interesting oxygen profile. The epilimnion is saturated or slightly over-saturated with oxygen but concentrations decline rapidly in the metalimnion to near zero from 20-30 feet (6-10 m). This phenomenon is likely due to a high density of oxygen-consuming bacteria which are decomposing settling plankton whose

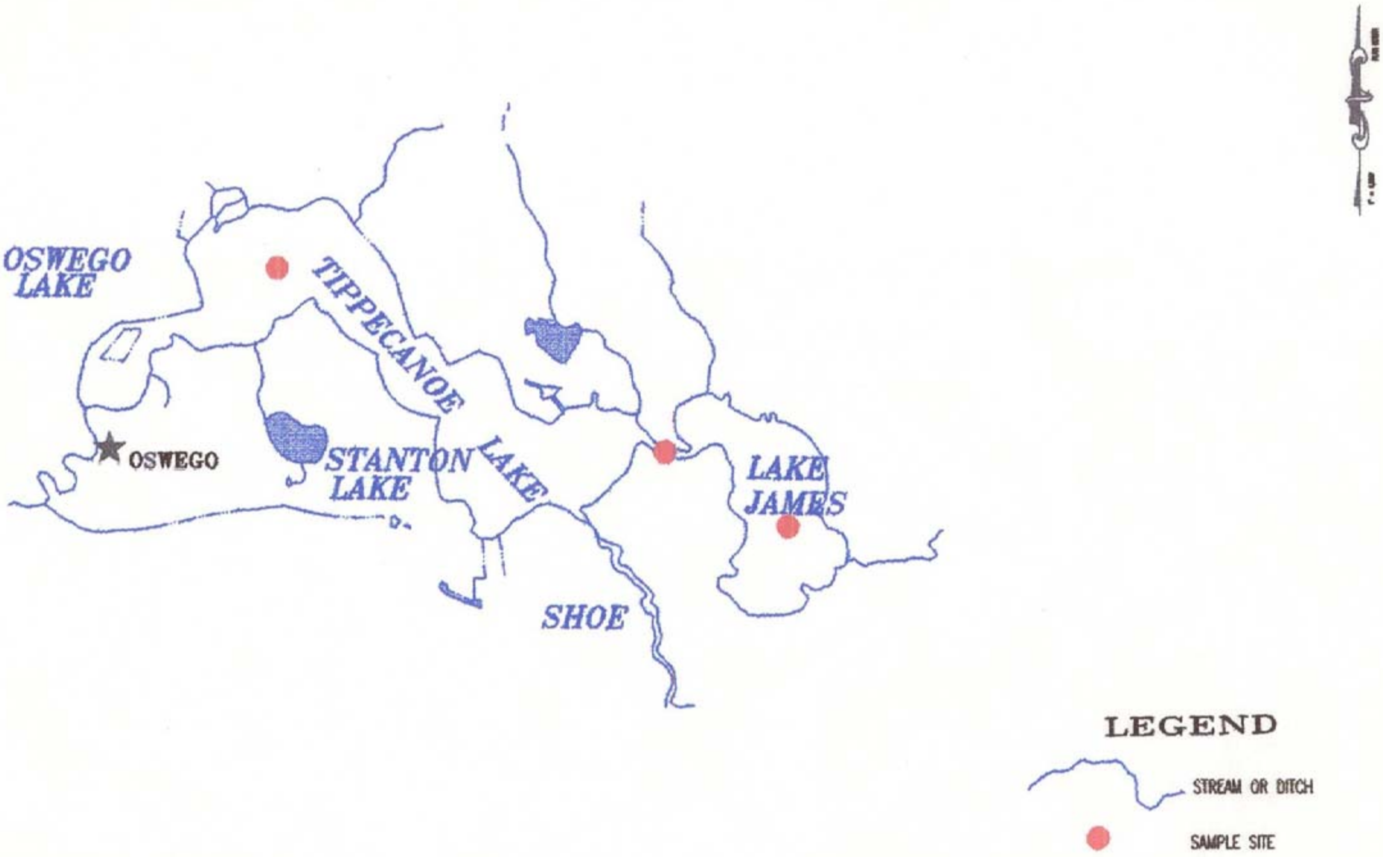

FIGURE 5.
LAKE TIPPECANOE FEASIBILITY STUDY
LAKE WATER SAMPLE LOCATIONS

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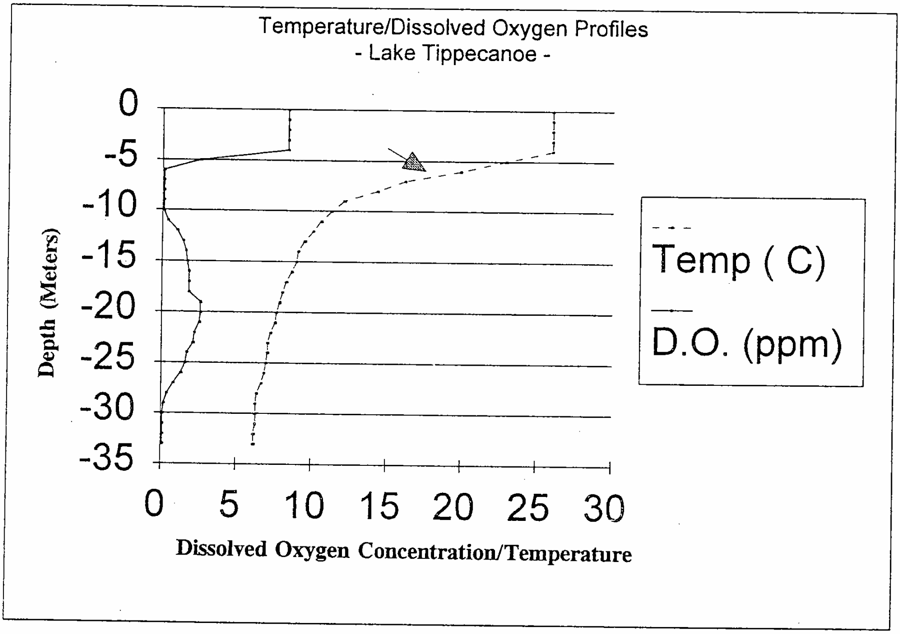

FIGURE 6.
TEMPERATURE AND DISSOLVED OXYGEN PROFILES - LAKE TIPPECANOE

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descent slows when they reach the denser waters of the metalimnion. Lower decomposition rates from 30-65 feet (10-20 m) give the appearance of increasing oxygen concentrations but oxygen concentrations are simply returning to normal. Below 65 feet (20 m), decomposition again increases and oxygen concentrations decrease until available oxygen is consumed at 98 feet (30 m).

Water quality data for Lake Tippecanoe is presented in Table 3. Phosphorus and nitrogen are the primary plant nutrients in lakes. Concentrations of these nutrients are relatively low in the lake. Higher concentrations of phosphorus in the hypolimnion indicate that phosphorus is being liberated from the sediments due to the anoxic, chemically-reducing conditions there. There is an undetectable amount of soluble reactive phosphorus in the epilimnion because this dissolved form is rapidly taken up and used by algae. Because ammonia is a by-product of the decomposition of organic matter, ammonia concentrations are also higher in the hypolimnion where decomposition rates are high and where ammonia is not oxidized. Table 4 summarizes water quality parameters determined for 279 Indiana lakes during July-August 1989-91 by the Indiana Clean Lakes Program. This table can be used to compare values determined for Lake Tippecanoe with other Indiana lakes.

Alkalinity is a measure of the water's ability to resist change in pH, or acid content. It is also referred to as acid neutralizing capacity or buffering capacity. This buffering action is important because it ensures a relatively constant chemical and biological environment in lakes. Alkalinity is determined largely by the availability and chemistry of carbonate in water. Sources of carbonate to natural waters include limestone (calcium carbonate) and carbon dioxide. The high alkalinity concentrations indicate that Lake Tippecanoe is a well-buffered system.

Values of pH are higher in the epilimnion where the process of photosynthesis consumes carbon dioxide, a weak acid. The lack of photosynthesis in the hypolimnion, and the liberation of carbon dioxide by respiring bacteria keep pH levels lower. Conductivity values, a measure of dissolved ions, are normal for Indiana lakes.

The relatively low Secchi disk transparency in Lake Tippecanoe is a reflection of the plankton population density. The median Secchi disk transparency for 279 Indiana lakes sampled during July-August 1989-91 by the Indiana Clean Lakes Program was 5.2 feet (1.6 m) so this is similar to the transparency reported here (5.9 feet or 1.8 m, Table 4). The epilimnetic total suspended solids concentration was 3.0 ppm and this also affects transparency and light penetration. The 1% light level, which limnologists use to determine the lower limit where photosynthesis can occur, extended to a depth of 15 feet (4.6 m) in Lake Tippecanoe.

Plankton include algae (microscopic green plants) and zooplankton (microscopic, primarily crustacean animals). Ecologically, the algae are the chief primary producers in lakes and form the base of the aquatic food chain. Zooplankton are the primary consumers of algae and are, in turn, preyed upon by many fish. Ecologically healthy lakes need healthy, balanced plankton populations.

TABLE 3. Lake Tippecanoe Water Quality Data.

PARAMETER	EPILIMNION	HYPOLIMNION	MEAN	EUTROPHY POINTS
Total Phos. (mg/l)	0.010	0.064	0.037	1
SRP (mg/L)	0.0	0.053	0.027	0
NO_3 (mg/L)	0.001	0.450	0.226	0
NH_4 (mg/L)	0.002	0.221	0.112	0
Org-N (mg/L)	0.767	0.513	0.640	2
Alkalinity (mg/L)	165.9	183.4	174.7	NA
pH	8.19	7.32	NA	NA
Conductivity (μmhos)	430	373	402	NA
Secchi disk (m)	1.8	NA	NA	0
D.O. (% sat. @ 5')	104	NA	NA	0
D.O. (% oxic)	73	NA	NA	1
% Light transmission at 3'	28	NA	NA	4
Plankton density (#/L)	NA	NA	6334	2
Blue-green algae dominance	NA	NA	YES	10
Chlorophyll *a* (mg/L)	5.03	NA	NA	NA
Total Suspended Solids (mg/L)	3.00	0.80	1.90	NA
TOTAL				20

TABLE 4. Water quality characteristics of Indiana 379 Indiana lakes sampled by the Indiana Clean Lakes Program, 1989-91.

	NO_3 (mg/L)	NH_4 (mg/L)	Org. N (mg/L)	SRP (mg/L)	TP (mg/L)	Secchi (m)
MAX.	16.68	13.67	9.71	0.67	2.09	8.00
MIN.	0.05	0.015	0.05	0.00	0.005	0.25
MEDIAN	0.36	0.69	1.28	0.03	0.09	1.60

TABLE 5. Plankton Species Composition in Lake Tippecanoe on 8/7/96

SPECIES	ABUNDANCE (#/L)
Blue-Green Algae (Cyanophyta)	
Anabaena	1212
Aphanizomenon	2644
Aphanocapsa	787
Coelosphaerium	63
Merismopedia	31
Microcystis	268
Oscillatoria	31
Green Algae (Chlorophyta)	
Pediastrum	787
Mougeotia	31
Ulothrix	189
Diatoms (Bacillariophyceae)	
Fragilaria	47
Synedra	693
Other Algae	
Ceratium	157
Mallomonas	16
Peridinium	47
Zooplankton	
Calanoid Copepod	2.2
Cyclopoid Copepod	1.9
Daphnia	4.9
Diaphanasoma	0.4
Keratella	16
Nauplii	13.1
Other Rotifers	94

Lake Tippecanoe's plankton community is not particularly dense throughout the euphotic zone (6334 cells/L) but it is dominated by blue-green algae which make up 80% of the plankton by number (Table 5). Blue-green algae are the type of algae which most often form blooms and which are often unpalatable to the zooplankton, the primary consumers in lakes. Overall, there is a good diversity of algae and zooplankton species in Lake Tippecanoe. The most abundant taxa in the lake was *Aphanizomenon*, a very small, filamentous blue-green alga. Chlorophyll *a*, which is a measure of the primary pigment in algae, is a direct measure of algal productivity. In the one-meter sample, the chlorophyll *a* concentration was 5.03 mg/L.

Lake James-
Temperature and oxygen profiles for Lake James are shown in Figure 7. Lake James is strongly stratified and the epilimnion is only seven feet (2 m) deep. This is not uncommon in smaller lakes where wind mixing is limited. A large portion of Lake James is anoxic - from 16 feet (5 m) to the lake bottom. This greatly restricts available habitat for fish and plankton.

Because much of Lake Tippecanoe's watershed first drains into Lake James, the water quality of Lake James is expected to be worse than that of Lake Tippecanoe. This is confirmed by the water quality data in Table 6. Total and soluble phosphorus, ammonia, plankton density, and chlorophyll *a* are all higher in Lake James than in Lake Tippecanoe. It is also apparent that the extensive hypolimnetic anoxia results in substantial release of nutrients from the sediments. These nutrients, in turn, nourish the phytoplankton. Organic nitrogen, nitrate and total suspended solids are slightly lower in Lake James.

The plankton of Lake James are again dominated by blue-green algae (71.5%), especially *Aphanizomenon* (Table 7). Total plankton density was 7129 cells per liter.

Between-the-Lakes Channel-
The Between-the-Lakes channel is the outlet from Lake James and an inlet to Lake Tippecanoe. This channel is regularly disturbed by watercraft which stir up bottom sediments as they travel between the lakes and this can have adverse consequences on water quality. Because of the shallow depth in the channel, we only sampled at 3.2 feet (1 m) below the surface.

Concentrations for total phosphorus, soluble phosphorus, nitrate, ammonia and organic nitrogen in the channel are worse than that in the epilimnion of Lake Tippecanoe so the channel can be considered a source of nutrients to the lake (Table 8). Concentrations of total and soluble phosphorus and organic nitrogen in the channel are greater than those in Lake James' epilimnion from which they flowed and this is most likely due to physical stirring by channel flow and boat traffic. Nitrate and ammonia concentrations in the channel are less than that in Lake James and likely reflect nitrification and dentrification processes in the channel wetland.

Plankton densities are less than those in either Lake James or Lake Tippecanoe for the most part because a shallow, flowing channel is not ideal plankton habitat (Table 9). Blue-green algae again dominated the plankton (69%).

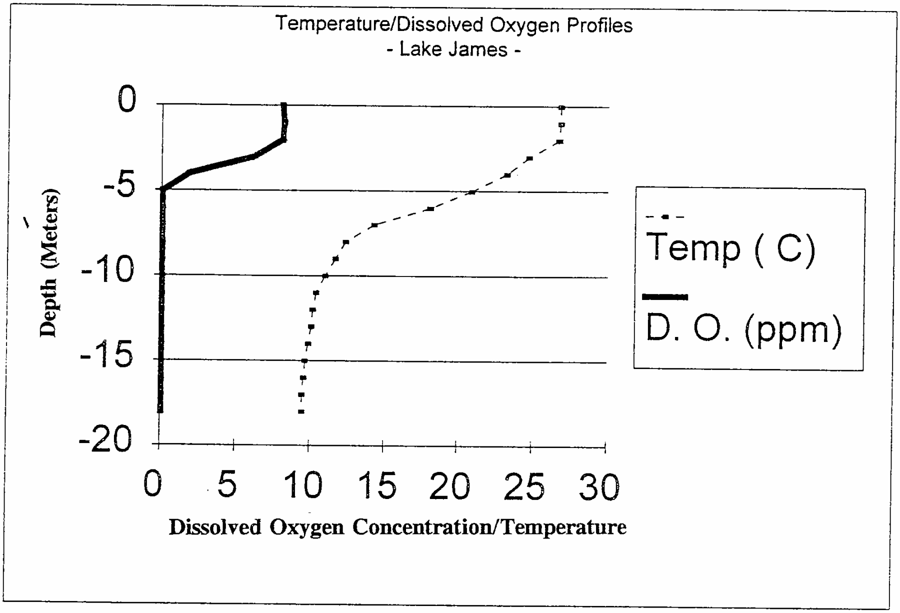

FIGURE 7.
TEMPERATURE AND DISSOLVED OXYGEN PROFILES - LAKE JAMES

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TABLE 6. Lake James Water Quality Data.

PARAMETER	EPILIMNION	HYPOLIMNION	MEAN	EUTROPHY POINTS
Total Phos. (mg/l)	0.001	0.185	0.098	3
SRP (mg/L)	0.0	0.162	0.081	3
NO_3 (mg/L)	0.055	0.001	0.028	0
NH_4 (mg/L)	0.073	1.771	0.922	3
Org-N (mg/L)	0.647	0.493	0.570	1
Alkalinity (mg/L)	176.1	175.8	176.0	NA
pH	8.15	7.31	NA	NA
Conductivity (μmhos)	461	400	431	NA
Secchi disk (m)	2.2	NA	NA	0
D.O. (% sat. @ 5')	102	NA	NA	0
D.O. (% oxic)	22	NA	NA	4
% Light transmission at 3'	23	NA	NA	4
Plankton density (#/L)	NA	NA	7129	2
Blue-green algae dominance	NA	NA	YES	10
Chlorophyll *a* (mg/L)	7.34	NA	NA	NA
Total Suspended Solids (mg/L)	2.200	1.166	1.683	NA
			TOTAL	30

TABLE 7. Plankton Species Composition in Lake James on 8/7/96.

SPECIES	ABUNDANCE (#/L)
Blue-Green Algae (Cyanophyta)	
Anabaena	535
Aphanizomenon	4140
Aphanocapsa	205
Coelosphaerium	94
Lyngbya	63
Microcystis	31
Oscillatoria	31
Scenedesmus	16
Green Algae (Chlorophyta)	
Pediastrum	205
Mougeotia	31
Ulothrix	551
Diatoms (Bacillariophyceae)	
Fragilaria	31
Synedra	740
Other Algae	
Ceratium	252
Mallomonas	110
Staurastrum	47
Zooplankton	
Calanoid Copepod	1.9
Cyclopoid Copepod	8.6
Daphnia	2.2
Nauplii	32.9
Keratella	79
Polyarthra	63
Other Rotifers	47

TABLE 8. Between-the-Lakes Channel Water Quality

PARAMETER	EPILIMNION	HYPOLIMNION	MEAN	EUTROPHY POINTS
Total Phos. (mg/l)	0.022	NA	NA	NA
SRP (mg/L)	0.002	NA	NA	NA
NO_3 (mg/L)	0.023	NA	NA	NA
NH_4 (mg/L)	0.021	NA	NA	NA
Org-N (mg/L)	1.455	NA	NA	NA
Alkalinity (mg/L)	174.5	NA	NA	NA
pH	8.0	NA	NA	NA
Conductivity (μmhos)	460	NA	NA	NA
Secchi disk (m)	>1.4	NA	NA	NA
D.O. (% sat. @ 5')	NA	NA	NA	NA
D.O. (% oxic)	100	NA	NA	NA
% Light transmission at 3'	26	NA	NA	NA
Plankton density (#/L)	NA	NA	4168	NA
Blue-green algae dominance	NA	NA	YES	NA
Chlorophyll *a* (mg/L)	3.32	NA	NA	NA
Total Suspended Solids (mg/L)	2.00	NA	NA	NA
			TOTAL	NA

TABLE 9. Plankton Species Composition in the Channel Between-the-lakes on 8/7/96.

SPECIES	ABUNDANCE (#/L)
Blue-Green Algae (Cyanophyta)	
Anabaena	488
Aphanizomenon	1684
Aphanocapsa	567
Coelosphaerium	31
Microcystis	47
Lyngbya	63
Green Algae (Chlorophyta)	
Pediastrum	126
Ulothrix	220
Diatoms (Bacillariophyceae)	
Fragilaria	126
Synedra	519
Other Algae	
Ceratium	189
Mallomonas	63
Peridinium	31
Zooplankton	
Cyclopoid Copepod	2.2
Daphnia	0.7
Diaphanasoma	0.7
Keratella	63
Nauplii	9.7
Polyarthra	16
Other Rotifers	94

TROPHIC STATE

The most widely-used standard for assessing the condition of a lake is by considering its *trophic state*. The trophic state of a lake refers to its overall level of nutrition or biological productivity. Trophic categories include: *oligotrophic, mesotrophic, eutrophic* and *hypereutrophic*, with productivity increasing from oligotrophic to eutrophic. Some characteristics of these trophic states are:

> *Oligotrophic* - clear water, dissolved oxygen is present in the hypolimnion (bottom waters), can support salmonid fisheries such as cisco.
>
> *Mesotrophic* - water less clear, decreasing dissolved oxygen in the hypolimnion, loss of salmonids.
>
> *Eutrophic* - transparency less than two meters, no dissolved oxygen in hypolimnion during summer, weeds and algae abundant.

The changes in a lake from oligotrophic to a higher trophic state is called *eutrophication*. Eutrophication is defined as the loading of inorganic nutrients, organic matter and sediment to lakes and reservoirs at rates sufficient to increase the potential for high biological production and to lead to a decrease in lake volume. By this definition, high phosphorus alone does not make a lake eutrophic. The phosphorus levels must also cause an increase or potential increase in plant production and/or sedimentation.

Trophic State Indices-
The large amount of water quality data collected during lake water quality assessments can be confusing to evaluate. Because of this, Indiana and many other states use a trophic state index (TSI) to help evaluate water quality data. A TSI condenses water quality data into a single, numerical index. Different index (or eutrophy) points are assigned for various water quality concentrations. The index total, or TSI, is the sum of individual eutrophy points for a lake.

The most widely used and accepted TSI is one developed by Bob Carlson (1977) called the Carlson TSI (Figure 8). Carlson analyzed total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among the three parameters. He developed mathematical equations for these relationships which are the basis for the Carlson TSI. Using this index, a TSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll *a* or total phosphorus. Data for one parameter can also be used to predict a value for another. The TSI values range from 0 to 100. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass.

In the early 1970's, biologists with the Indiana State Board of Health developed a multi-parameter Eutrophication Index (Indiana TSI) for use in understanding water quality differences between two particular lakes. The Indiana TSI has been used since that time to evaluate changes in all Indiana lakes. The Indiana TSI ranges from 0 to 75 total points. The TSI totals are grouped into the following three lake quality classifications:

CARLSON'S TROPHIC STATE INDEX

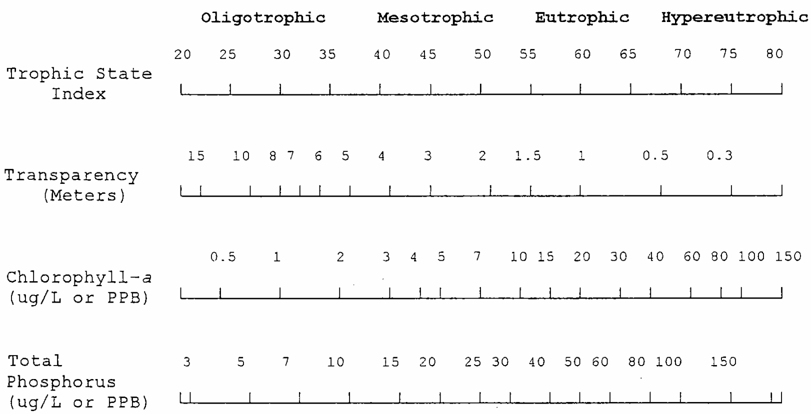

FIGURE 8.
CARLSON'S TROPHIC STATE INDEX

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TSI Total	Water Quality Classification
0-25	oligotrophic
26-50	mesotrophic
51-75	eutrophic

Indiana TSI scores are calculated from ten water quality parameters (Table 10). Eutrophy points are assigned according to the value of the measured parameter. The mean of an epilimnetic and hypolimnetic water sample is used to calculate the parameter value from which the eutrophy points for phosphorus and nitrogen are assigned. For example, a total phosphorus concentration of 0.043 ppm would be assigned 2 eutrophy points while a concentration of 0.29 would be assigned 4 eutrophy points. The eutrophy points assigned for each parameter are summed to give the total TSI score.

The Indiana TSI is heavily weighted toward plankton. Up to 35 of the 75 total points (47%) are assigned to plankton parameters. Thus, there can be large TSI differences between lakes due only to plankton. For example, ten points are assigned if the plankton is dominated by blue-green algae. Secchi disk transparency is also an absolute scale (0 or 6 points) rather than a variable scale, such as for total phosphorus. These factors cause the Indiana TSI to occassionally conclude different results than Carlson's or other TSIs in use around the country.

TABLE 10. The Indiana Trophic State Index

	Parameter and Range	Eutrophy Points
I.	Total Phosphorus (ppm)	
	A. At least 0.03	1
	B. 0.04 to 0.05	2
	C. 0.06 to 0.19	3
	D. 0.2 to 0.99	4
	E. 1.0 or more	5
II.	Soluble Phosphorus (ppm)	
	A. At least 0.03	1
	B. 0.04 to 0.05	2
	C. 0.06 to 0.19	3
	D. 0.2 to 0.99	4
	E. 1.0 or more	5
III.	Organic Nitrogen (ppm)	
	A. At least 0.5	1
	B. 0.6 to 0.8	2
	C. 0.9 to 1.9	3
	D. 2.0 or more	4

IV. Nitrate (ppm)

A.	At least 0.3	1
B.	0.4 to 0.8	2
C.	0.9 to 1.9	3
D.	2.0 or more	4

V. Ammonia (ppm)

A.	At least 0.3	1
B.	0.4 to 0.5	2
C.	0.6 to 0.9	3
D.	1.0 or more	4

VI. Dissolved Oxygen: Percent Saturation at 5 feet from surface

A.	114% or less	0
B.	115% 50 119%	1
C.	120% to 129%	2
D.	130% to 149%	3
E.	150% or more	4

VII. Dissolved Oxygen:
Percent of measured water column with at least 0.1 ppm dissolved oxygen

A.	28% or less	4
B.	29% to 49%	3
C.	50% to 65%	2
D.	66% to 75%	1
E.	76% 100%	0

VIII. Light Penetration (Secchi Disk)

A.	Five feet or under	6

IX. Light Transmission (Photocell)
Percent of light transmission at a depth of 3 feet

A.	0 to 30%	4
B.	31% to 50%	3
C.	51% to 70%	2
D.	71% and up	0

X. Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface:

A.	less than 3,000 organisms/L	0
B.	3,000 - 6,000 organisms/L	1
C.	6,001 - 16,000 organisms/L	2
D.	16,001 - 26,000 organisms/L	3
E.	26,001 - 36,000 organisms/L	4
F.	36,001 - 60,000 organisms/L	5
G.	60,001 - 95,000 organisms/L	10
H.	95,001 - 150,000 organisms/L	15
I.	150,001 - 500,000 organisms/L	20
J.	greater than 500,000 organisms/L	25
K.	Blue-Green Dominance: additional points	10

Trophic State of Lake Tippecanoe and Lake James-

TSI scores for Lake Tippecanoe and Lake James are given in Table 11. Using Indiana's TSI, Lake Tippecanoe scores within the oligotrophic category with 20 points and Lake James is considered mesotrophic with 30 points. In both cases, the Indiana TSI appears to understate the trophic state of these lakes.

Using Carlson's TSI, Lake Tippecanoe is mesotrophic for chlorophyll (46 points), meso-eutrophic for Secchi disk transparency (53 points) and eutrophic for total phosphorus (56 points). In ecologically balanced lakes, the Carlson TSI point totals should be equivalent for all three parameters. The differences indicate that algal production (chlorophyll) in Lake Tippecanoe is less than expected given the large amount of phosphorus in the lake, possibly due to the flushing rate of the lake or predation by the healthy zooplankton population. Large-bodied *Daphnia* are particularly effective grazers of algae and they are relatively abundant in the lake. Lower algal densities, in turn, make transparency better than Carlson's model would predict. Another likely reason for these differences is that mean phosphorus concentrations were used to calculate the TSI score and this resulted in a higher score. The hypolimnetic phosphorus is an important nutrient source which is mixed back into the lake at each spring and fall overturn.

Lake James scored higher than Lake Tippecanoe in Carlson's total phosphorus TSI (70 points = eutrophic) and chlorophyll TSI (52 points = meso-eutrophic); but slightly lower in Secchi disk TSI (50 points = meso-eutrophic). Again, the high hypolimnetic phosphorus concentrations likely over-weighted phosphorus in the TSI calculations.

In comparing the two lakes, Lake James has higher nutrient concentrations and significant anoxia in the hypolimnion which permits substantial release of phosphorus from the sediments. The lake's position upstream from Lake Tippecanoe means that degraded water from Lake James will continue to flow into and degrade the water quality of Lake Tippecanoe. A management program for Lake Tippecanoe must therefore include plans to manage water quality in Lake James.

TABLE 11. Summary of Trophic State Index Scores Using Mean Water Quality Data.

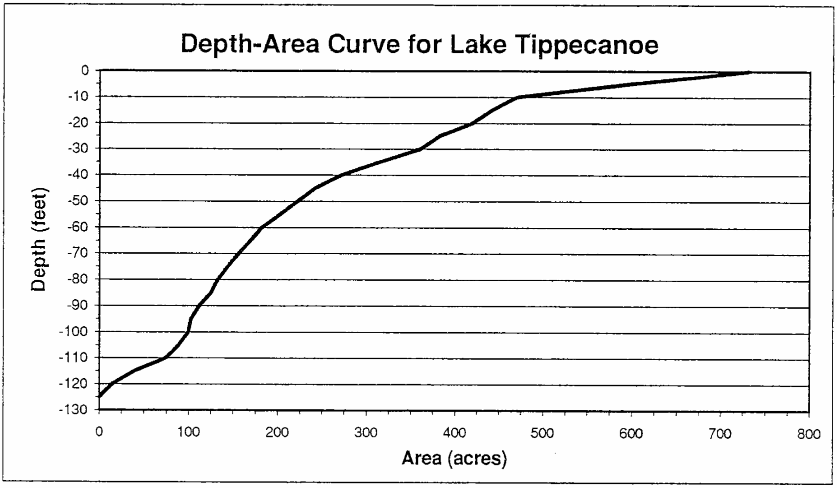
LAKE	Indiana TSI	Carlson's Secchi Disk TSI	Carlson's Total Phosphorus TSI	Carlson's Chlorophyll TSI
Tippecanoe	20	53	56	46
James	30	50	70	52

V. LAKE AND WATERSHED MORPHOMETRY

Table 12 summarizes the surface area, volume and other geographic information for Lake Tippecanoe. Depth-area and depth-volume curves (Figures 9 and 10) were prepared from the Indiana Department of Natural Resources bathymetric map of Lake Tippecanoe (Figure 11). These curves are extremely useful in illustrating important relationships between depth, volume and area. For example, if a particular rooted aquatic plant can grow in water up to ten feet deep, the potential habitat for this plant is about 470 acres (area of lake between 0-10 feet). Knowing this, cost estimates of weed control or other lake treatments can be easily calculated with a given area and water volume.

Table 12. Summary of Lake Tippecanoe and Watershed Morphometry

Surface Area	768 acres (311 hectares)
Maximum Depth	123 feet (37.5 meters)
Mean Depth	37.1 feet (11.3 meters)
Volume	28,491 acre-feet (35,143,000 cubic meters)
Shoreline Length	20.9 miles (33.6 kilometers)
Shoreline Development	1.6
Watershed Size	111.8 mi^2 (289.6 km^2)
Watershed:Lake Area Ratio	93:1



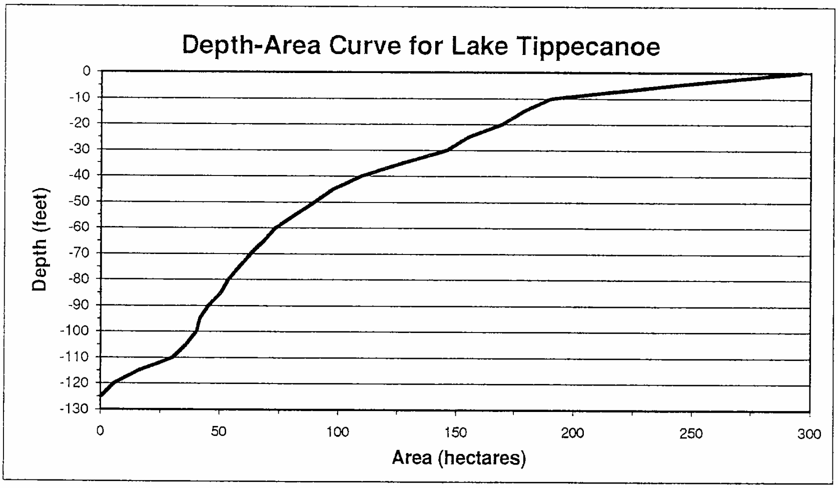


FIGURE 9.
DEPTH-AREA CURVES FOR LAKE TIPPECANOE

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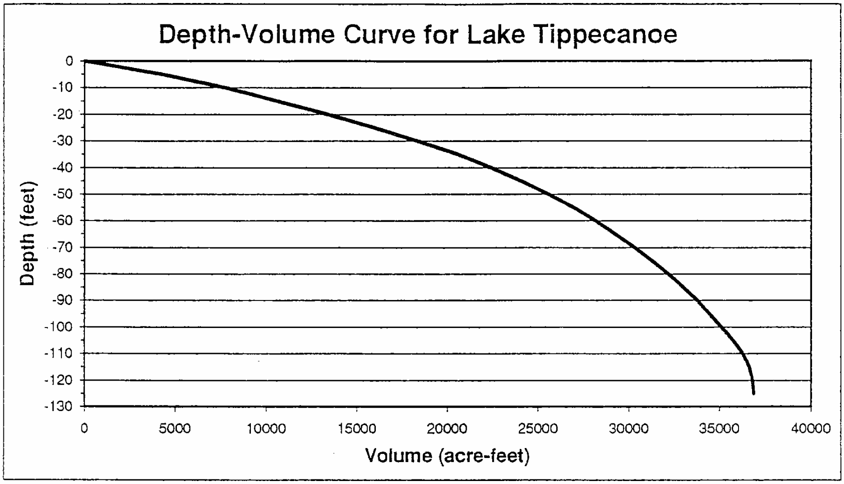

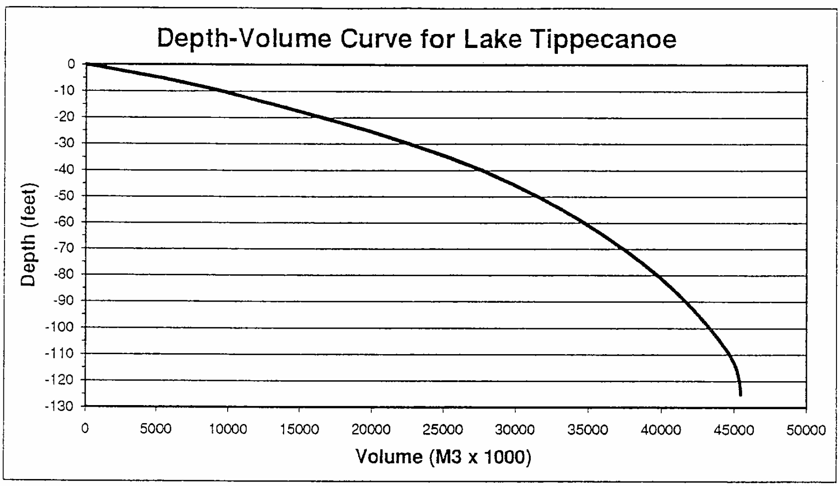

FIGURE 10.
DEPTH-VOLUME CURVES FOR LAKE TIPPECANOE

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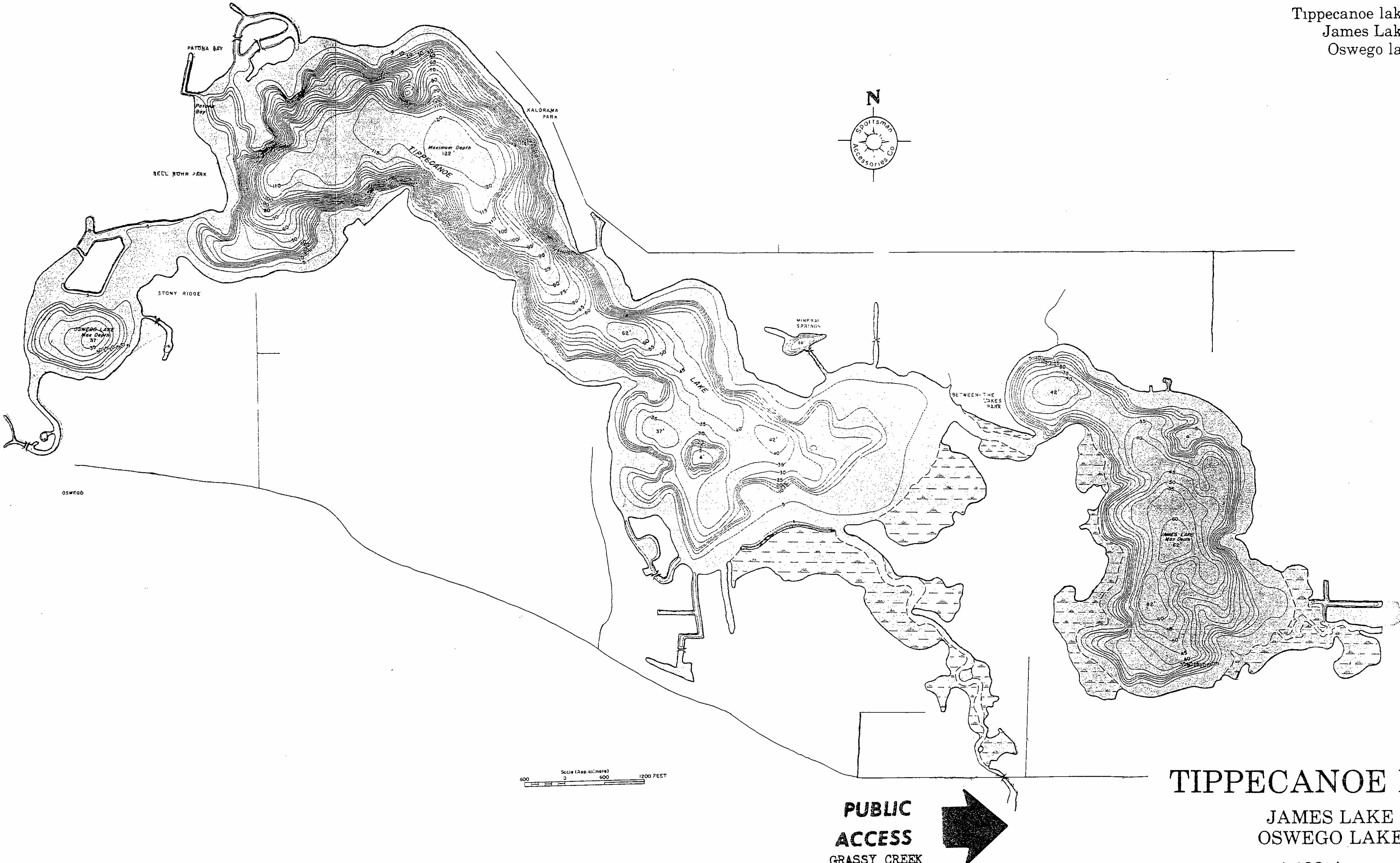
Tippecanoe lake 768 Acres
James Lake 282 Acres
Oswego lake 82 Acres



TIPPECANOE LAKE

JAMES LAKE
OSWEGO LAKE

1,132 Acres

Kosciusko County, Ind.

FIGURE 11
BATHYMETRIC MAP

VI. SEDIMENT CHARACTERISTICS

Lake sediments are the repository of nutrients, plant material and other heavier-than-water materials which are in the water column. Thus, analysis of sediments can lend insight to the long-term effects of lake processes. Sediment grab samples were taken from each of the water sampling locations in Lake Tippecanoe and Lake James and the channel using an Ekman dredge. With this device, we collected approximately the upper four inches of sediments at each site. These samples were dried and analyzed for: particle size distribution, organic matter, total phosphorus and total nitrogen.

The sand-silt-clay content of the two lakes is similar due to common parent geological material in the lake's watersheds (Table 13). The channel contains more of the denser sand-sized particles because the finer particles stay suspended in shallow water and are transported into Lake Tippecanoe. Lake James' sediments have more organic matter because of the higher algal production in the lake (the dead algae settles to the lake bottom throughout the year) and because anaerobic decomposition rates in the sediments are slower than aerobic decomposition. Channel sediments had noticeable vegetation growing on the bottom and this resulted in higher organic matter levels in the samples.

Lake James' sediments had higher phosphorus and nitrogen content than Lake Tippecanoe's. This reflects the higher concentration of nutrients in the lake's water and the higher algal production. The channel had the lowest phosphorus content because phosphorus does not adsorb to sand as much as to silt or clay. The vegetation collected along with the sediments likely raised the nitrogen content of the channel sediment sample. There are no standards or guidelines for sediment. However, comparison of the results to those of other Indiana lakes and reservoirs (Table 14) shows that the phosphorus content in Lake Tippecanoe's and James' sediments is relatively enriched. Under anoxic hypolimnetic conditions, this phosphorus can be a continuing source of nutrition to the lakes' algae populations.

Sediment cores were extracted from several lake inlets to determine relative sediment accumulation depths. Cores were taken at each stream's mouth and at other locations extending lakeward from the mouth. The coring device was pushed into the sediments until it stopped, presumably upon hitting the original gravel lake bed left behind by the glacier. Results indicate only a modest amount of sediment deposition at the mouths of the Tippecanoe River and Indian Creek (Table 15). However, 4.1 feet (124 cm) of sediment is deposited near the mouth of Hannabe-Walker Ditch. This suggests that this ditch is a significant sediment source to Lake Tippecanoe. The Hannabe-Walker ditch outlet was dredged in 1991 and 1995. This area has again filled in, presumably from both the constant supply of resuspended sediment in the channel between the lakes and from the high sediment loads in the ditch.

SUMMARY

A significant source of sediment is delivered to the lakes by Hannabe-Walker Ditch and lesser amounts by Indian Creek and the Tippecanoe River. The sediments of Lake James and Lake Tippecanoe are nitrogen and phosphorus enriched. These nutrients are re-entering the water column when the sediments are disturbed by power boats. Sediments and their adsorbed nutrient load can be managed by controlling bottom disturbance, trapping sediment in ditches and dredging. Bottom disturbance control is achieved most easily by observing no-wake boating restrictions in shallow water (< 8 feet or 2 m., Figure 12). Sediment traps and nutrient filters can be constructed within drainage ditches. Dredging at the mouths of Hannabe-Walker and Indian Creek would eliminate excess sediment and associated nutrients.

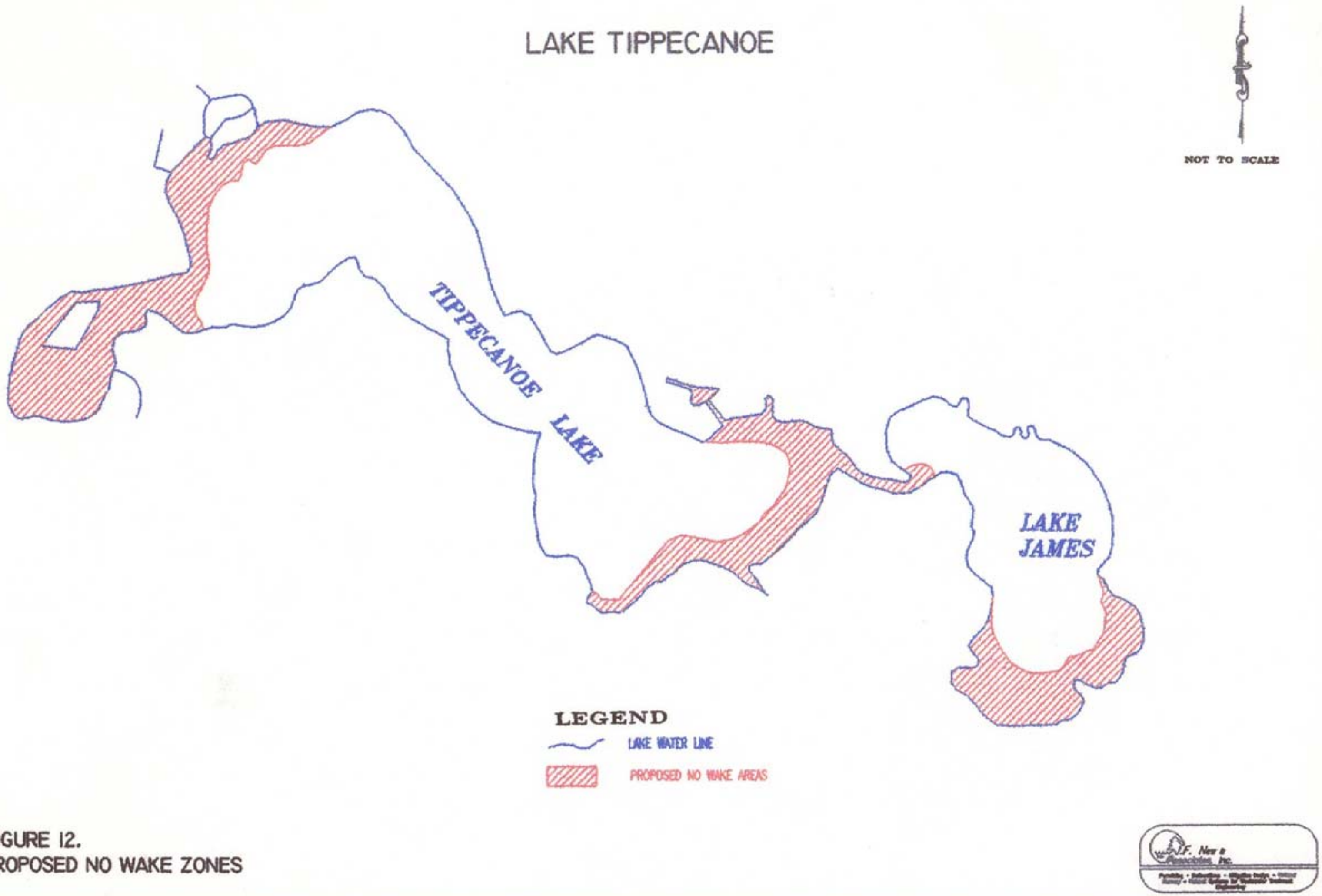


FIGURE 12.
PROPOSED NO WAKE ZONES

TABLE 13. Sediment composition and nutrients (based on dry sediment weights).

PARAMETER	TIPPECANOE	JAMES	CHANNEL
Particle Size	Sand - 20% Silt - 32% Clay - 48%	Sand - 17% Silt - 36% Clay - 47%	Sand - 46% Silt - 29% Clay - 25%
Organic Matter	12.7%	17.8%	12.4%
Total Phosphorus	1225 mg/kg	1383 mg/kg	801 mg/kg
Total Nitrogen	7282 mg/kg	9699 mg/kg	7364 mg/kg

TABLE 14. Sediment Characteristics of Indiana Lakes and Reservoirs.

WATER BODY	% ORGANIC MATTER	TOTAL PHOSPHORUS (mg/kg)
Big Turkey Lake	8.2	690
Cedar Lake	13.7	770
Lake Maxinkuckee	9.0	470
Palestine Lake	10.1	1150
Sylvan Lake	13.0	1290
Lake Wawasee	19.6	570
Mansfield Res.	1.9	1080
Mississinewa Res.	2.1	740
Monroe Res.	2.3	630

Source: Nelson and Orme (1980)

TABLE 15. Sediment Deposition at the Mouths of Several Inlet Creeks.

SITE	CORE LOCATION	SEDIMENT DEPTH (cm)
Tippecanoe River inlet to Lake James	at mouth	40
	30 m into lake	70
	60 m into lake	53
Hannabe-Walker Ditch	at mouth	80
	20 m into lake	124
Indian Creek	5 m into lake	0
	15 m into lake	52
	25 m into lake	62

VII. STREAM SAMPLING DATA

METHODS

The major streams flowing into and out of Lake Tippecanoe were sampled twice during this project - during base flow (6/26/96) and following a runoff event (7/18/96). The run off event was a 3.02 inch rainfall which is a one year event. In addition, approximately three inches of rain had fallen in the previous two weeks prior to this sampling and therefore ground conditions were saturated. These streams included (Figure 13):

1. Lake Tippecanoe outlet (at Armstrong Road)
2. Indian Creek (at Kalorama Road)
3. Hannabe-Walker Ditch (at 650 North Road)
4. Long Ditch/Rich Creek (at 650 North Road)
5. Tippecanoe River inlet (at 675 East Road)
6. Kuhn Ditch (at 600 North Road)
7. Grassy Creek (at 500 North Road)

At each site the following was determined:

- temperature
- dissolved oxygen
- pH
- alkalinity
- total phosphorus
- soluble reactive phosphorus
- nitrate+nitrite
- ammonia
- total organic nitrogen
- suspended solids
- fecal coliform bacteria
- discharge

Discharge could not be determined at the lake outlet or the Tippecanoe River inlet because the water was too deep to wade with the discharge measuring instrument.

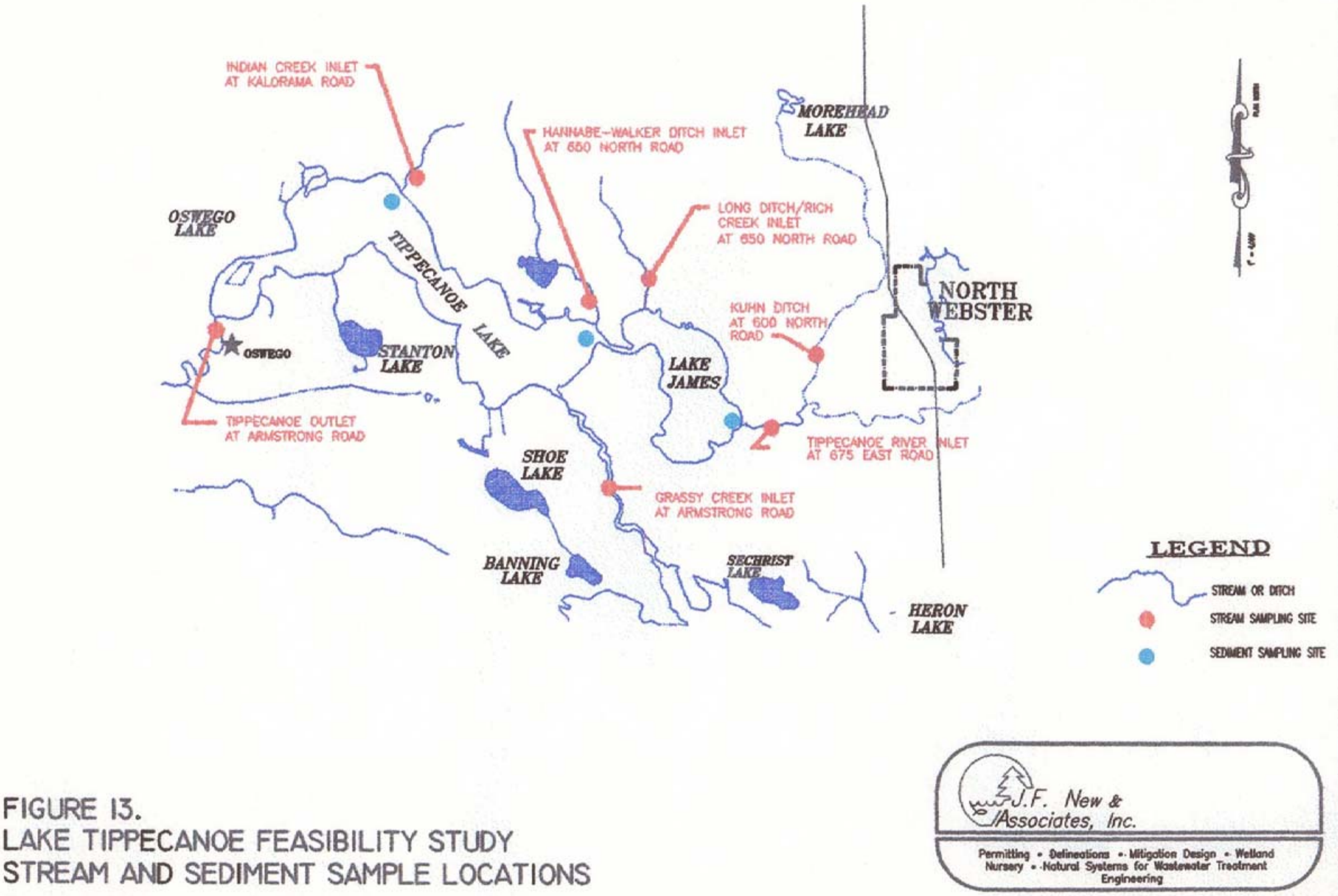


FIGURE 13.
LAKE TIPPECANOE FEASIBILITY STUDY
STREAM AND SEDIMENT SAMPLE LOCATIONS

RESULTS

Stream sampling results are given in Table 16. Temperatures in the streams varied from 15.0 ^{0}C to 27.0^{0}C. Those streams with cooler temperatures may have a greater proportion of groundwater. Stream temperatures are generally cooler than lake temperatures due to the groundwater influence and because there is less solar warming of shaded stream water.

Dissolved oxygen (D.O.) concentrations vary from 5.8 ppm to 9.4 ppm. Because D.O. varies with temperature (cold water can contain more oxygen than warm water), it is more relevant to consider D.O. saturation values. This refers to the amount of oxygen dissolved in water compared to the maximum possible when the water is saturated with oxygen. When water is saturated with oxygen, its saturation value is 100%. Values less than 100% occur in waters where decomposition consumes oxygen more quickly than it can be replaced by diffusion from the atmosphere or by production via plant photosynthesis. Oxygen saturation was lowest in Long Ditch, Kuhn Ditch and Grassy Creek during normal flows and in Hannabe-Walker Ditch and Tippecanoe River inlet following the precipitation event.

Alkalinity is lowest in the streams following the runoff event because during runoff, the alkalinity is diluted by rainwater and the runoff water moves across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional alkalinity (Figure 14).

Nutrient concentrations and total suspended solids are generally higher in all of the streams following the runoff event because the increased water flow results in increased erosion of soil and nutrients from the land. There are two useful ways to report water quality data in flowing water. *Concentrations* describe the mass of a particular material contained in a unit of water, for example milligrams of phosphorus per liter (mg/L). *Mass loading* on the other hand describes the mass of a particular material being carried in the stream per unit of time. For example, a high concentration of phosphorus in a stream with very little flow can deliver a smaller total amount of phosphorus to the lake than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids and bacteria actually delivered to the lake which are most important when considering the effects of these materials on a lake.

Total phosphorus concentrations were highest in Indian Creek, Hannabe-Walker Ditch and Long Ditch following the runoff event in July but Kuhn Ditch actually delivers more phosphorus to Lake Tippecanoe because it has a greater discharge of water (Figures 15 and 16). Hannabe-Walker Ditch delivers the next highest phosphorus loading to the lake. Thus, phosphorus management programs should concentrate on Kuhn and Hannabe-Walker ditches.

A similar situation occurs with nitrogen concentrations and loading following the runoff event (Figures 17 and 18). Hannabe-Walker Ditch, Indian Creek and Long Ditch have the highest concentrations of total nitrogen but Kuhn Ditch and Grassy Creek have the highest total nitrogen loadings. The high nitrogen loadings from Grassy Creek may result from scouring of vegetation and organic matter from the wetlands along the creek.

Long Ditch, Indian Creek and Hannabe-Walker Ditch had the highest concentrations of total suspended solids during the runoff event but the highest loadings of suspended solids were from Hannabe-Walker Ditch, Kuhn Ditch and Long Ditch (Figures 19 and 20). The higher storm discharges likely caused greater soil erosion in these watersheds than in the other watersheds.

TABLE 16. Lake Tippecanoe Stream Sampling Data.

SITE	Temp (C)	D.O. (ppm)	D.O. Sat (%)	pH	Alkalinity (mg/L)	TP (mg/L)	SRP (mg/L)	NO3 (mg/L)	NH4 (mg/L)	TKN (mg/L)	Org. N (mg/L)	TSS (mg/L)	Fecal Coliform (#/100 ml)	Discharge (cfs)	Discharge (liters/sec)	TSS (g/sec)	TP (mg/sec)	Org N (mg/sec)	TKN (g/sec)	Coliform (#/min)
Outlet																				
6/26/96	23.5	8.1	95.3	8.4	278.1	0.044	0.002	0.527	0.065	0.78	0.72	6.8	10				0			
7/18/96	24.0	6.4	76.0	8.1	169.5	0.043	0.002	0.168	0.047	0.72	0.67	9.4	225				0			
Indian Cr.																				
6/26/96	15.0	9.6	95.2	8.1	278.1	0.086	0.067	2.525	0.091	0.04	nd	2.4	230	0.20	5.7	0.01359	0.4871	0	0.00025	217.12
7/18/96	19.0	8.4	90.5	7.7	122.1	0.399	0.145	4.008	0.454	1.93	1.47	202.3	8090	4.59	130.0	26.2928	51.8655	191.344	0.25036	175268
Hannabe Walker																				
6/26/96	17.0	9.4	97.3	7.9	236.1	0.084	0.035	8.127	0.079	0.12	0.04	8.2	120	7.67	217.2	1.7855	18.246	8.03693	0.0252	4344.29
7/18/96	21.0	6.6	74.1	7.2	60.3	0.531	0.394	5.042	0.491	2.17	1.68	134.0	2820	29.64	839.4	112.48	445.724	1408.52	1.82067	394520
Long Ditch																				
6/26/96	20.5	6.1	67.0	7.7	258.6	0.066	0.035	5.308	0.093	0.01	nd	9.5	1200	1.41	39.9	0.38094	2.63546	0	0.00028	7986.24
7/18/96	22.0	6.8	77.8	7.5	100.5	0.570	0.373	4.638	0.163	1.56	1.40	251.0	7360	8.61	243.8	61.2026	138.986	341.125	0.38087	299105
Kuhn Ditch																				
6/26/96	19.0	6.3	67.9	7.7	264.2	0.087	0.022	2.466	1.762	2.68	0.92	6.0	10	2.47	70.0	0.4197	6.08568	64.3544	0.18761	116.584
7/18/96	21.0	6.2	69.6	7.4	99.9	0.257	0.168	2.328	0.193	1.50	1.30	44.0	6730	84.28	2386.8	105.02	613.41	3112.4	3.57305	2.7E+06
Tippe River Inlet																				
6/26/96	25.0	7.0	84.7	8.1	177.0	0.053	0.008	0.668	0.062	0.91	0.85	4.5	69							
7/18/96	23.0	6.1	71.1	7.9	146.8	0.108	0.032	0.622	0.063	1.11	1.05	17.0	2540							
Grassy Creek																				
6/26/96	27.0	5.8	72.8	8.1	173.5	0.042	0.005	1.143	0.221	0.89	0.67	2.0	10	62.77	1777.6	3.55529	74.6611		1.58211	2962.74
7/18/96	25.0	6.4	77.5	8.0	153.4	0.062	0.004	0.381	0.031	0.82	0.79	2.5	1380	102.84	2912.4	7.28107	180.571		2.37654	669859

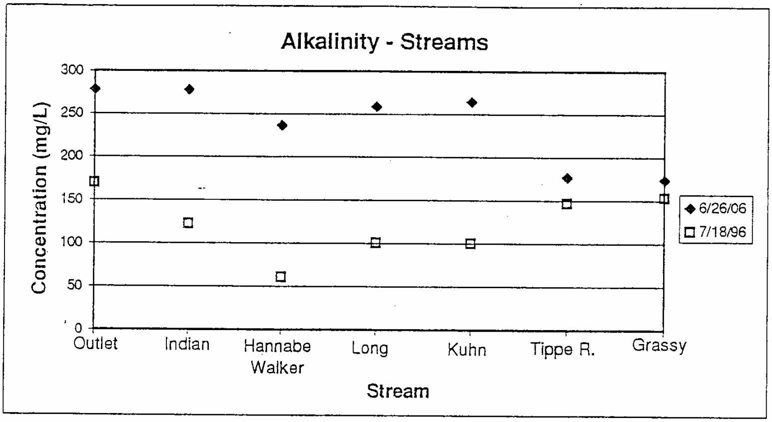


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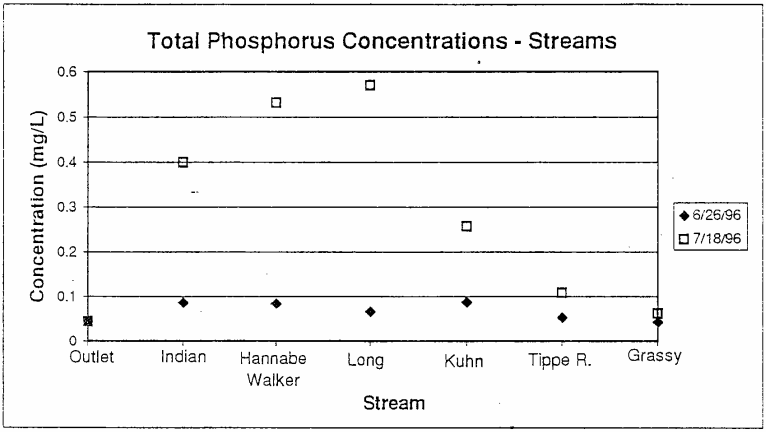
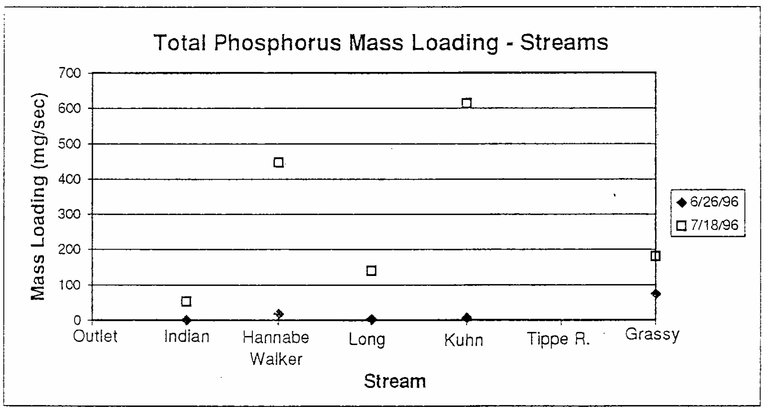
FIGURE 14
ALKALINITY IN STREAMS





FIGURES 15 and 16
PHOSPHORUS IN STREAMS

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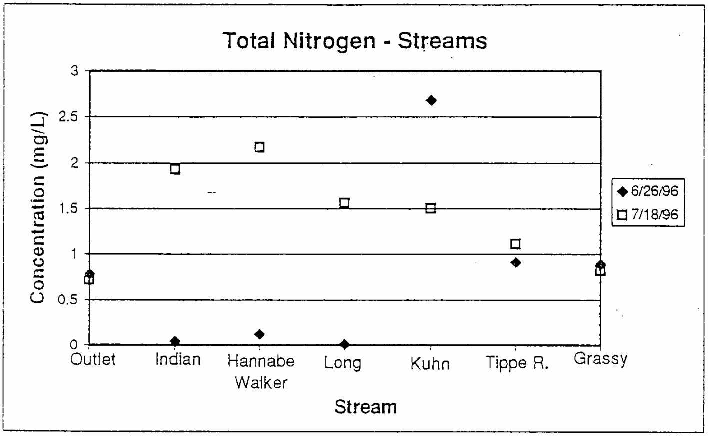

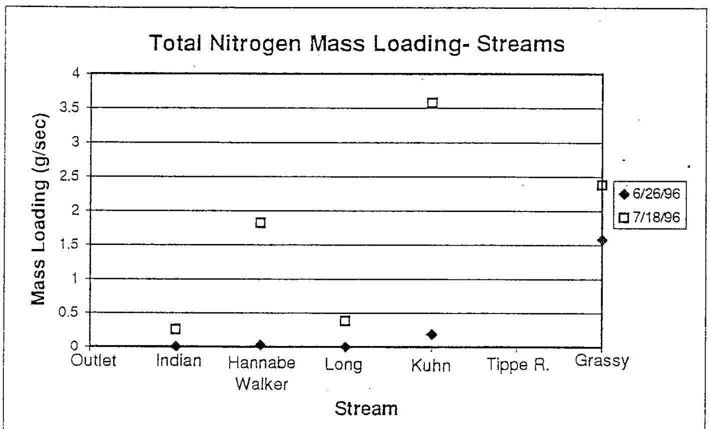

FIGURES 17 and 18
NITROGEN IN STREAMS

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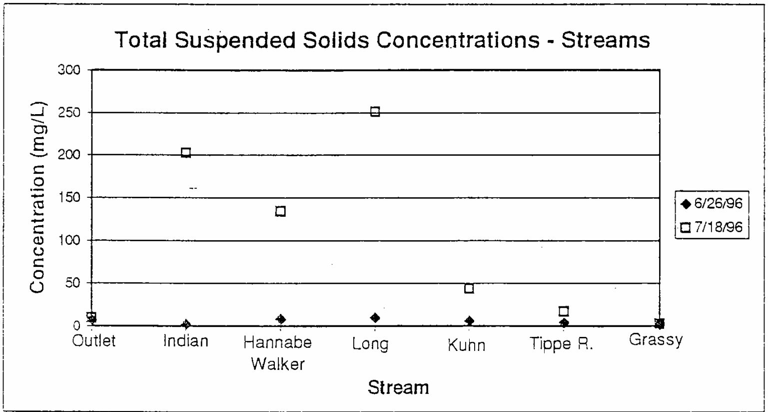

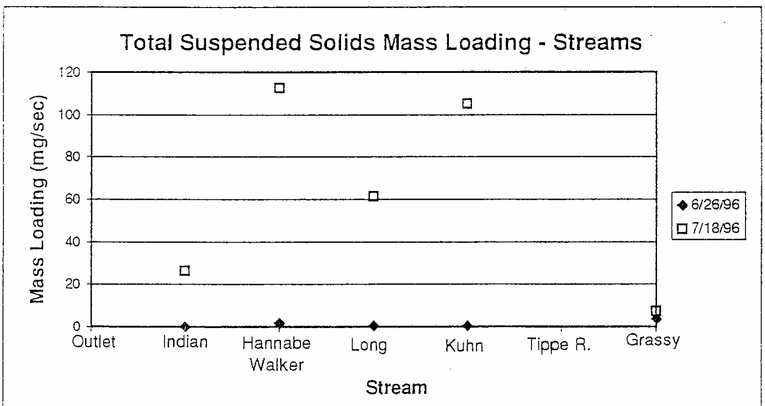

FIGURES 19 and 20
SUSPENDED SOLIDS IN STREAMS

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Indian Creek, Long Ditch and Kuhn Ditch had the highest concentrations of fecal coliform bacteria during the runoff event (Figure 21). Because health standards are based on concentrations, these three streams have the greatest bacterial contamination and management efforts for bacteria should concentrate on sources within the watersheds of these streams. However, because of their greater discharges, Kuhn Ditch and Grassy Creek deliver the most fecal coliform bacteria to Lake Tippecanoe (Figure 22). Contamination from fecal coliform is a human health concern as these bacteria associate with human pathogens. Sources of these bacteria can be from septic tank leachate, surface or tiled runoff from pastures or feedlots or from native animal waste living within close proximity to a stream.

SUMMARY

Kuhn Ditch, Hannabe-Walker Ditch and Grassy Creek consistently rank at the top for mass loading of nutrients, sediment and bacteria to Lake Tippecanoe. Indian Creek has the highest concentration of fecal coliform bacteria. Management activities should target these streams.

VIII. WATER BUDGET

An annual water budget for Lake Tippecanoe was prepared using mean annual discharge data recorded at a U.S.G.S. gauging station immediately downstream from the lake's dam (Stewart et al., 1995) and from mean precipitation data from the U.S.D.A. Soil Conservation Service (Staley, 1989). The mean annual discharge rate from Lake Tippecanoe during the period of 1950 - 1995 was 105.0 cubic feet per second (cfs). This yields a total discharge of 93,654,086 cubic meters (m^3) annually from the lake. Inputs of water to Lake Tippecanoe are from:

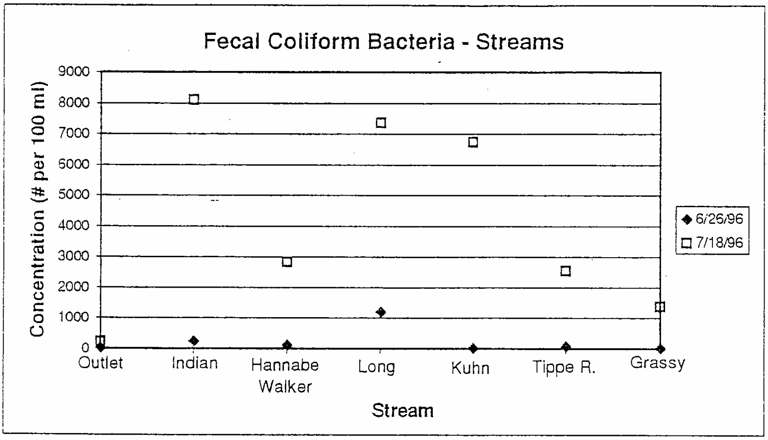
direct precipitation to the lake
- channelized runoff from streams draining into the lake
- sheet runoff from land immediately adjacent to the lake
- groundwater

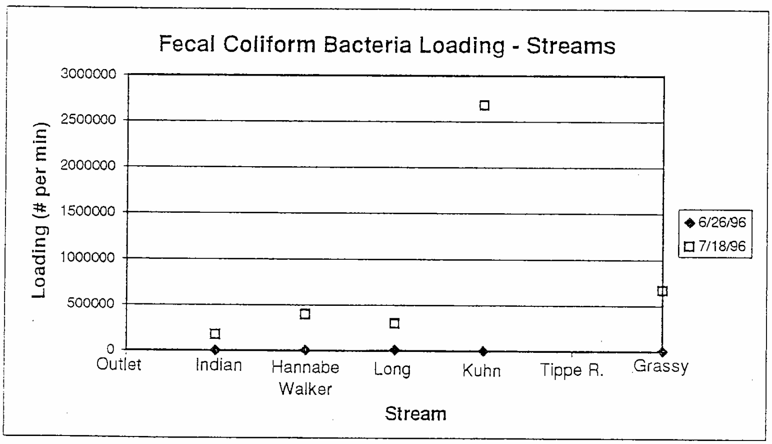
Water leaves the lake from:

- discharge from the outlet
- evaporation
- groundwater

Seasonal trends in discharge and direct precipitation are shown in Figure 23. April, June and July are historically the months when precipitation is highest - about four inches per month on average. Less than two inches of precipitation enters the lake during an average January and February. Because evaporation losses are highest in the summer, discharge from the lake is lowest in July, August, and September. Annual snow melt and high precipitation in the early Spring result in the highest seasonal discharges from the lake at that time - nearly 200 cfs.

The total amount of water flowing into and out of Lake Tippecanoe amounts to about 2.66 lake volumes per year. This is referred to as the *hydraulic flushing rate*. At this rate, the lake's volume is completely replaced on average once every 4.5 months.





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FIGURES 21 and 22
BACTERIA IN STREAMS

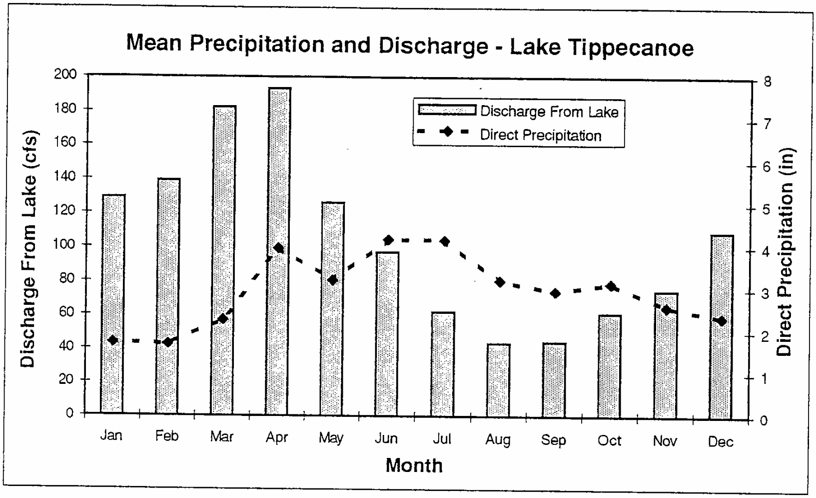

FIGURE 23
PRECIPITATION and DISCHARGE
LAKE TIPPECANOE

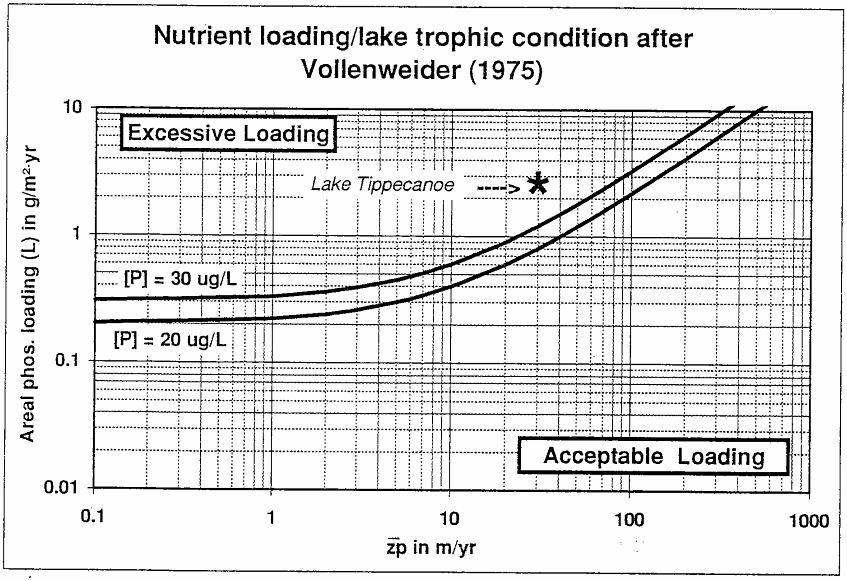

FIGURE 24
NUTRIENT LOADING and
TROPHIC CONDITION

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IX. PHOSPHORUS MODELING

Although the two sets of water quality samples collected from the major inlet streams provided valuable insight into nutrient dynamics in Lake Tippecanoe's watershed, the limited data are not sufficient to estimate annual nutrient loadings to the lake. Therefore, standard phosphorus loading models have been used to estimate total phosphorus loading from the watershed.

To estimate phosphorus losses from various land uses in the watershed, aerial photographs were used to measure the amount of agriculture, pasture, forest and urban land uses for each of the six major sub-watersheds draining into Lake Tippecanoe. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies, and calculated phosphorus export coefficients for each land use. Conservative estimates of these phosphorus export coefficient values were used, which are expressed as kilograms of phosphorus lost per hectare of land per year, and multiplied them by the amounts of land in each of the land use categories to derive an estimate of annual phosphorus export (kg/year) for each land use per watershed (Table 17). Direct phosphorus input via precipitation was measured by multiplying mean annual precipitation in Kosciusko County (0.885 m/yr) times the surface area of Lake Tippecanoe ($3.11 \times 10^6 m^2$) times a typical phosphorus concentration in Indiana precipitation ($0.03\ g/m^3$). The phosphorus load from septic systems was then estimated by multiplying the number of homes with lake frontage (approximately 400) times an estimated 3 people per home, times an occupancy rate of 1/2 or 3/4 year per home, times a phosphorus export coefficient of 0.6 or 1.8 kg per capita-year (Reckhow and Simpson, 1980). The results, shown in Table 18, yielded an estimated 16,455.2 - 17,715.2 kg of phosphorus exported from the watershed per year.

Phosphorus loading from all sources is summarized in Table 19. Remember that the precipitation and septic system totals are best estimates of what reaches the lake, while the watershed totals are estimates of what is exported from individual land uses. Not all of this phosphorus reaches Lake Tippecanoe. For example, phosphorus lost from a particular corn field in the upper reaches of the Kuhn Ditch watershed can get trapped by grass filter strips, land located down gradient from the field, or in the ditch sediments. In addition, some of the phosphorus lost from land uses in the Tippecanoe River or Grassy Creek watersheds is trapped by other lakes before it reaches Lake Tippecanoe. The model used is not sophisticated enough to account for all of these processes, making estimates of how much phosphorus reaches the lake very difficult.

The amount of phosphorus loading required for the mean total phosphorus concentration in the lake can be estimated by using a phosphorus loading model such as the widely-used Vollenweider (1975) model. Vollenweider's empirical model says that the concentration of phosphorus ([P]) in a lake is proportional to the aerial phosphorus loading (L, in g/m^2 lake area - year), and inversely proportional to the product of mean depth ($\overline{Z}$) and hydraulic flushing rate (ρ) plus a constant (10):

$$[P] = \frac{L}{10 + \overline{Z}\rho}$$

TABLE 17. Estimated Phosphorus Export by Watershed.

		Indian Creek		Hannabe- Walker		Longs Ditch	
Land Use	P-export (kg/ha-yr)	Area (ha)	P-export (kg)	Area (ha)	P-export (kg)	Area (ha)	P-export (kg)
Agriculture	0.9	42.5	38.25	149.7	134.73	64.8	58.32
Pasture	0.2	36.4	7.28	64.8	12.96	42.5	8.50
Forest	0.1	42.5	4.25	28.3	2.83	30.4	3.04
Urban	0.5	0	0	0	0	0	0
WATERSHED TOTALS		121.4	49.78	242.8	150.52	137.7	69.86

		Kuhn Ditch		Tippecanoe River		Grassy Creek	
Land Use	P-export (kg/ha-yr)	Area (ha)	P-export (kg)	Area (ha)	P-export (kg)	Area (ha)	P-export (kg)
Agriculture	0.9	380.4	342.36	8540	7686	6870	6183
Pasture	0.2	161.9	32.38	270	54	270	54
Forest	0.1	64.8	6.48	2640	264	3640	364
Urban	0.5	32.4	16.2	670	335	810	405
WATERSHED TOTALS		639.5	397.42	12120	8339	11590	7006

TABLE 18. Estimated Phosphorus Loading by Source (theoretical).

Watershed Phosphorus Exported = 16,012.6 kg/yr

Precipitation Phosphorus = 82.6 kg/yr
(0.885 m/yr)(3.11 x $10^6 m^2$)(0.03 g/m^3)

Septic Systems (low estimate) = 360 kg/yr
(400 dwellings)(3 people/dwelling)(0.5/yr)(0.6 kg P/capita-yr)
or
Septic Systems (high estimate) = (1,620 kg/yr)
(400 dwellings)(3 people/dwelling)(0.75/yr)(1.8 kg P/capita-yr)

TOTAL PHOSPHORUS LOAD = 16,455.2 - 17,715.2 kg/yr

Indian Creek		Acres	Hannabe-Walker		Acres	Longs Ditch		Acres
area	121.4	0.4047	area	242.8	0.4047	area	137.7	0.4047
p-Export	49.78	49.13058	p-Export	150.52	98.26116	p-Export	69.86	55.72719
Kg-P/ha/yr	0.410049		Kg-P/ha/yr	0.6199341		Kg-P/ha/yr	0.507335	

Kuhn Ditch		Acres	Tippe River		Acres	Grassy Creek		Acres
area	639.5	0.4047	area	12120	0.4047	area	11590	0.4047
p-Export	397.42	258.80565	p-Export	8339	4904.964	p-Export	7006	4690.473
Kg-P/ha/yr	0.621454		Kg-P/ha/yr	0.6880363		Kg-P/ha/yr	0.604487	

Revised figures for
Tables 17–18

Tippecanoe Watershed	
Indian Creek	121.4
Hannabe-Walker	242.8
Longs Ditch	137.7
Kuhns Ditch	639.5
Tippecanoe	12120
Grassy Creek	11590
ha	24851.4
total P	16012.6
P/ha/yr.	0.644334

TABLE 19. Distribution of Estimated Phosphorus Loading (theoretical)

SOURCE	PHOSPHORUS LOAD (kg/yr)	% OF TOTAL PHOSPHORUS LOAD	% OF WATERSHED AREA
Indian Creek	49.8	0.3	0.5
Hannabe-Walker	150.5	0.9	1.0
Longs Ditch	69.9	0.4	0.6
Kuhn Ditch	397.4	2.2 - 2.4	2.6
Tippecanoe River	8339.0*	40.7 - 50.8*	48.8
Grassy Creek	7006.0*	39.5 - 42.7*	46.6
Direct Precipitation	82.6	0.5	-
Septic Systems	360 - 1,620**	2.2 - 9.1	-

* Numbers are arttificially high due to inability of model to estimate phosphorus uptake in upstream lakes
** Range due to variance in functionality of septic systems and average residency

During the 7 August 1996 sampling, the mean epilimnetic phosphorus concentration was 0.01 mg/L and the mean hypolimnetic phosphorus concentration was 0.064 mg/L. Using the respective volumes of the epilimnion and hypolimnion from the depth-volume curve (Figure 10), a volume-weighted mean phosphorus concentration for the lake of 0.057 mg/L is derived. By using mean depth and flushing rate within Vollenweider's model and solving for L, an areal phosphorus loading rate of 2.28 g/m^2-yr is obtained. This means that in order to get the annual mean phosphorus concentration of 0.057 mg/L in the lake, 2.28 grams of phosphorus must be delivered to each square meter of lake surface per year. At this areal loading rate, 7,090 kg of phosphorus must be delivered to the entire lake each year to yield the concentration measured. Although watershed calculations show the potential phosphorus delivered by the entire watershed at 16,455.2 kg/yr, the 7,090 kg/yr value was estimated from what was actually measured in the lake, and is the more reasonable estimate of annual phosphorus load to Lake Tippecanoe.

The significance of this areal loading rate is better illustrated in Figure 24 in which aerial phosphorus loading is plotted against the product of mean depth and flushing rate. Overlaid on this graph are curves, based on Vollenweider's model, which represent an acceptable loading rate that yields a phosphorus concentration in lake water of 20 μg/L (0.02 mg/L) or less, and an unacceptable loading rate that yields a phosphorus concentration of 30 μg/L or more. Lake Tippecanoe's loading rate is within the excessive loading portion of the graph.

Figure 24 can also be used to evaluate management needs. For example, areal phosphorus loading would have to be reduced to 1.20 g/m^2-yr to result in a mean lake water concentration lower than 30 μg/L. This represents a reduction in phosphorus mass loading to the lake of 3,358.8 kg, a 20.5% reduction in total phosphorus loading.

X. WATERSHED LAND USE

HIGHLY ERODIBLE LAND

Hippensteel (1989) reported that the Grassy Creek watershed had 35% of its land surface classified as Highly Erodible Land (HEL). Kuhn Ditch had 16% of its land surface classified as HEL (Hippensteel, 1989). If assumptions are made that the average HEL acreage for the entire 112 square mile Lake Tippecanoe watershed is 25%, that 50% of the HEL acreage is currently cropped, and that 50% of cropped land is conventional tillage with 15 ton/acre/year soil loss with the other 50% in no-till or mulch management having 5 tons/acre/year soil loss, than the potential soil loss is 6,908,400 tons per year from just the HEL acres in the entire watershed (4,878,720 acres x 0.25 x 0.5 x 0.5 x 15) + (4,878,720 x 0.25 x 0.5 x 0.5 x 5). If you assume an average soil loss rate of 2 tons/acre/year from the remainder of the watershed than the total potential soil loss for the Lake Tippecanoe watershed becomes 13,416,480 tons per year (4,878,720 x 0.75 x 2) + 6,908,400).

Much of this eroded soil does not immediately leave the fields from which it originated, or is trapped in depressions and vegetated borders along waterways. However, the necessity of soil management to control this potential loss is very apparent. The Soil and Water Conservation District (SWCD) has been very active in Kosciusko County. The SWCD has been working with major landowners to implement erosion control plans on HEL ground. Their work includes design and cost sharing of grassed waterways, vegetated filter strips, and smaller dams to control runoff from agricultural fields. The SWCD staff can assist property owners with Natural Resource Conservation Service (NRCS) and Farm Services Agency (FSA) cost share and set aside programs as well. Current cost share programs are included as Appendix A.

In addition, The Indiana Department of Natural Resources (IDNR) - Division of Soil Conservation offers grants under the Lake and River Enhancement Program (LARE) to assist property owners or Lake Associations with diagnostic studies, design studies, and construction of erosion and nutrient reduction structures. Applications for funding are due by January 31 each year and grants are awarded in July of the same year. This report was funded by the LARE program.

HYDRIC SOIL AND WETLANDS

Figure 25 depicts the hydric soils (USDA-SCS, Soil Survey of Kosciusko County) and Figure 26 depicts the existing wetlands (USFWS - National Wetland Inventory Map, 1984) within the vicinity of the Lake Tippecanoe system. Since hydric soils developed under saturated or wetland conditions, they are a good indicator of the historical amount of wetland present within a watershed. The Kuhn Ditch watershed had the largest amount of wetland areas historically (238.5 ac, 96.5 ha) and has sustained the greatest numerical loss, with only 99 acres (40 ha) of wetlands remaining (60% loss). As a percentage of wetland to watershed area, Long Ditch and Hannabe-Walker Ditch have each lost 90% of their respective wetland areas. Long Ditch wetlands were reduced from 97 acres (39.3 ha) to 9.6 acres (3.9 ha), while the Hannabe-Walker drainage basin had approximately 107 acres (43.3 ha) of wetlands with only 11 acres (4.5 ha) remaining. Indian Creek's drainage area has been modified by tile drainage but was believed to contain approximately 45 acres (18.2 ha) of wetlands with only 13.6 acres (5.5 ha) remaining.

The percentage of historical wetland area within the four drainages to the north of Lake Tippecanoe was 19% of the total land surface (486.9 ac/197 ha). The remaining wetland area within those same drainages is only 3.9% (133.5 ac/54 ha). This 73% loss of total wetland area is similar to estimates for the entire state. These wetland areas have been either drained for agriculture or dredged and filled for residential use. Wetlands serve as nutrient sinks and filters removing much of the summer phosphorus and nitrogen loading and trapping a majority of the suspended sediments. This loss in wetland area causes significant increases in the amount of nitrogen and phosphorus delivered by streams. Replacing the functional value of the wetlands would help reduce the nutrient load to the lake.

NATURAL AREAS AND RARE, THREATENED AND ENDANGERED SPECIES

The Indiana Natural Heritage Database was checked by IDNR Division of Nature Preserves staff. Table 20 summarizes the three areas of concern. The Tippecanoe River supports a fairly diverse fish and mussel community which includes several rare and endangered species. Two high quality natural habitats are also found in the vicinity of Lake Tippecanoe; the Ball State Nature Preserve at the mouth of Grassy Creek and Kalorama Park Woods. The Nature Preserve is a large high quality wetland between Lake James and Tippecanoe managed by the Division of Nature Preserves. Kalorama Park Woods is a mature mesic forest found on the north side of Kalorama Road just east of the Tippecanoe Country Club.

TABLE 20. RARE, THREATENED AND ENDANGERED SPECIES

Type	Scientific Name	Common Name	Status
Tippecanoe River Species			
Fish	*Coregonus Artedi*	Cisco	SSC
	Hybopsis Amblops	Bigeye Chub	WL
Mollusk	*Epioblasma Torulosa Rangiana*	Northern Riffleshell	SE
	Lampsilis fasciola	Wavy-Rayed Lampmussle	SE, LE
	Ligumia Recta	Black Sandshell	WL
	Pleurobema Clava	Clubshell	SE, LE
	Phychobranchus fasciolaris	Kidneyshell	SSC
	Toxolasma Lividum	Purple Lilliput	SSC, C2
	Toxolasma Parvum	Lilliput	WL
Kalorama Park Woods			
Plant	*Carex Woodii*	Pretty Sedge	WL
	Pyrola Elliptica	Elliptical-leaf Wintergreen	WL
Ball Wetlands Nature Preserve			
Plant	Pyrola Elliptica	Elliptical-leaf Wintergreen	WL
	Carex Alata	Broadwing Sedge	WL
	Carex Bebbii	Bebb's Sedge	ST
	Cornus Amomum ssp Amomum	Silky Dogwood	SE
	Matteuccia Struthiopteris	Ostrich Fern	SR
	Polygonum Hydropiperides	Swamp Smartweed	SE
	Prunus Pennsylvanica	Fire Cherry	SR
	Ribes Hirtellum	SmootthGooseberry	WL
	Sparganium Androcladum	Branching Bur-Reed	ST
	Wolffiella Floridana	Sword Bogmat	SX
Bird	*Cistothorus Palustris*	Marsh Wren	SE
	Ixobrychus Exilis	Least Bittern	SE
Reptile	*Clonophis Kirtlandii*	Kirtland's Snake	ST, C2
	Nerodia Erythrogaster Neglecta	Copperbelly Water Snake	ST, PT

Key: State Level: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list.
Federal Level: LE=endangered, C2=species at risk, PT=proposed threatened

SEWAGE TREATMENT

The Lake Tippecanoe Property Owners, Inc. contracted with Bonar and Associates, Inc. in 1995-1996 to conduct a preliminary study of the need and costs associated with installing a sewer system to serve the residents surrounding Lake Tippecanoe. The study concluded that a collection system and treatment plant were necessary due to the poor soil adsorption capabilities and density of homes in the vicinity of the lakes. A Conservancy District was proposed as a mechanism to establish a governing authority for the implementation of the sewer system. The Conservancy District proposal failed in a referendum vote in July 1996.

Septic systems currently deliver a minimum of 5% and as much as 22.8% the phosphorus loading to the lake based on measured concentration of lake water phosphorus and known phosphorus loss rates. This minimum estimate assumes an average of three people for 1/2 year residency and fully functioning septic system with leach field. The high estimate assumes an average of three people per home for 3/4 year residency and a poorly functioning or failed septic system. More importantly, high fecal coliform bacteria concentrations, as measured by the Lake Association and sampling efforts for this study, are indicative of potential pathogen contamination in the water column. These coliform bacteria and their associated pathogens leach directly to the lake and ground water from poorly drained and overloaded septic fields presenting a serious health hazard to all lake users.

The density of homes near the lake shore and the predominance of homes in areas where ground water is within three feet of the surface, preclude the majority of septic systems from ever being fully functional. Developing a sewage treatment system for all residential and commercial establishments within 500 feet (150 m.) of the lake should be an immediate priority for landowners and users of the Lake Tippecanoe system.

SEAWALLS

Approximately 60% of the 20.9 miles (33.6 Km) of shoreline around Lake Tippecanoe, Lake James and Oswego Lake has been armored with concrete seawalls for erosion and flood prevention. Much of that seawall has been placed in areas that were previously wetlands. Seawalls demarcate a sharp boundary between land and water. Whereas, natural shorelines have a transition zone of those areas that are occasionally wet to those areas that are permanently wet. This vegetated transition zone serves for filtering nutrients and sediment from overland flow, as an exit or entry point for ground water recharge and provides critical habitat for aquatic and terrestrial wildlife species. Placing concrete or steel barriers at this transition zone serves as only temporary erosion protection while eliminating nutrient filtering capacity and critical wildlife habitat. An alternative to concrete or steel is natural stone or vegetated breakwaters. Vegetated or stone breakwaters should be promoted and encouraged by the Lake Association.

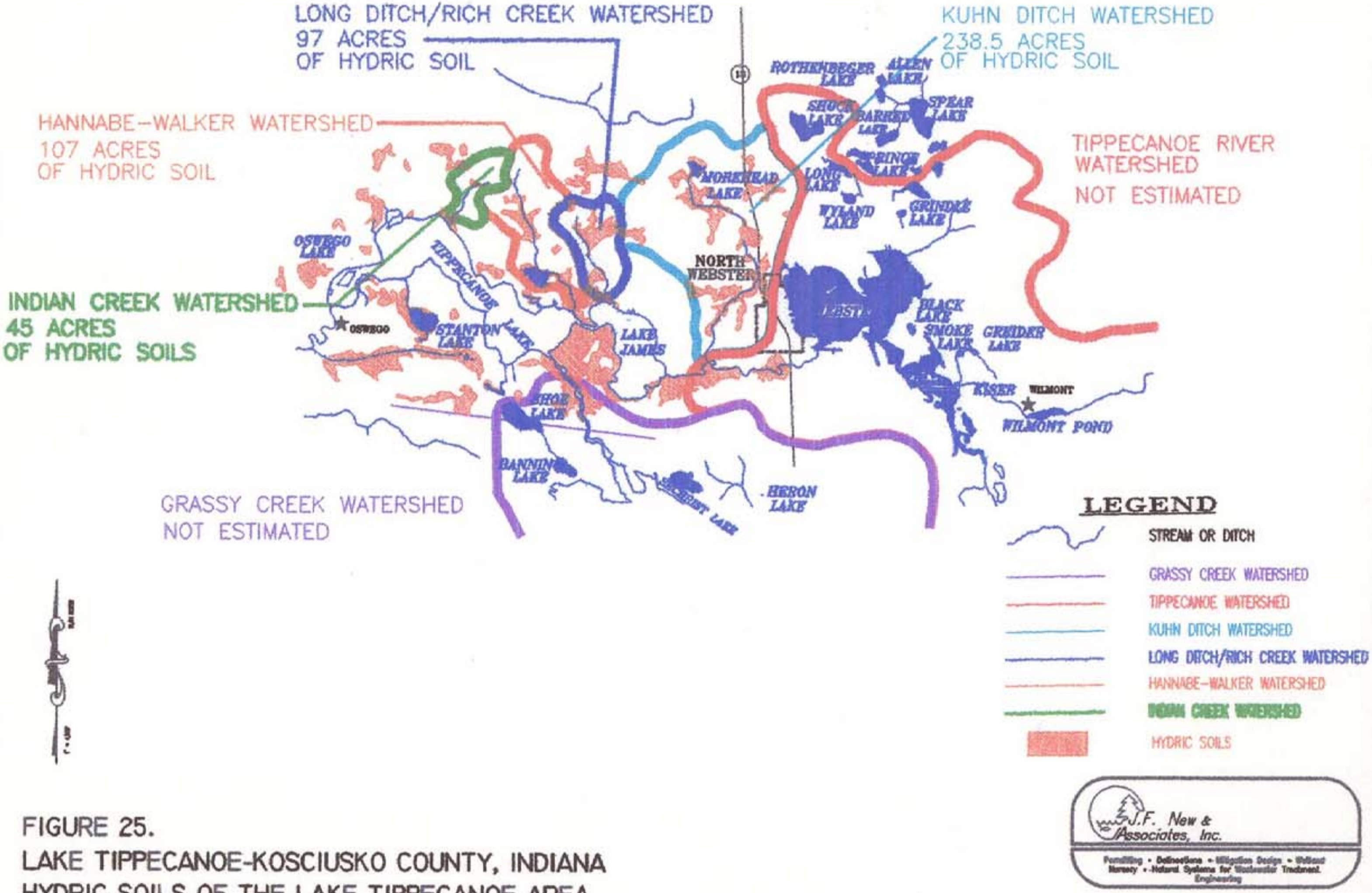


FIGURE 25.
LAKE TIPPECANOE-KOSCIUSKO COUNTY, INDIANA
HYDRIC SOILS OF THE LAKE TIPPECANOE AREA

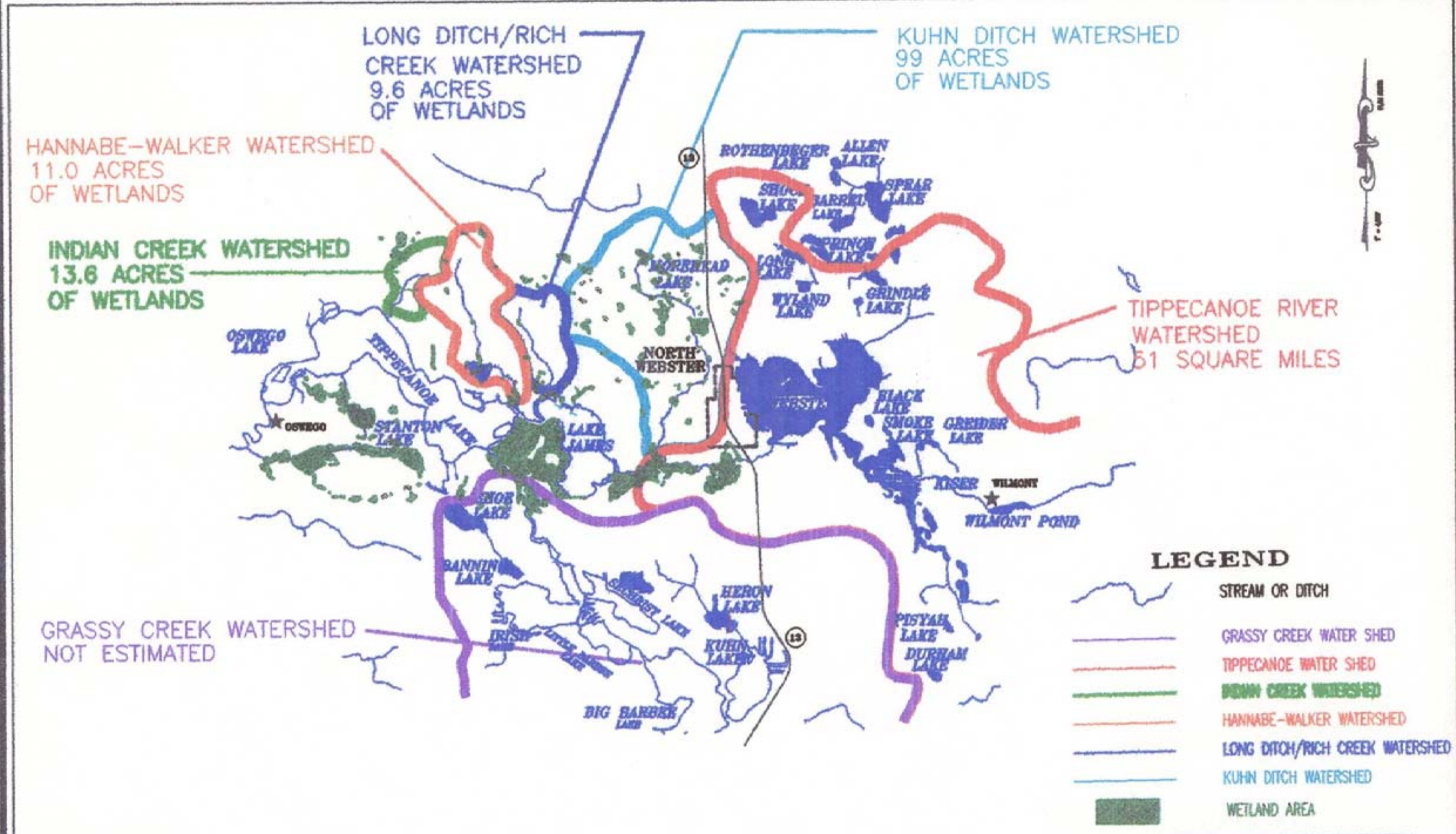


FIGURE 26.
LAKE TIPPECANOE-KOSCIUSKO COUNTY
WETLANDS OF THE LAKE TIPPECANOE AREA

XI. MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Lakes located on a river system are not only influenced by land use activities in their immediate watershed but also by conditions existing in upstream lakes and rivers. For example, lakes in the headwaters of a river system are often less productive because there is less watershed draining into them. Under some conditions, however, lakes lower in the system may also be less productive if the upstream lakes act as settling basins for watershed sediments and nutrients. This can elevate nutrient concentrations in those upstream lakes. However, if the flow of water through the system is great enough, and point and nonpoint source inputs high enough, sediments and nutrients may have insufficient time to settle and can flush through the upstream lakes to downstream lakes.

There is evidence of both of these processes in the Lake Tippecanoe system. On the Tippecanoe River chain, the headwater lake (Crooked) has a low Indiana TSI score of 11 (Table 21). Big Lake has a slightly higher Indiana TSI (27) and both Smally and Baugher Lakes' TSI's are higher still. As TSI increases, Secchi disk transparency declines in these lakes. Significant settling and/or processing of nutrients must occur in these deep lakes because the TSI for the next lake in the chain (shallow Wilmot Pond) drops sharply (Secchi disk transparency improves too). TSI scores rise again as the river flows through The Backwaters, Lake Webster and Lake James. The depth of Lake James promotes settling and the shallow channel outlet allows only surface water to flow into Lake Tippecanoe. There is sufficient watershed area above the lake at this point that discharge to Lake Tippecanoe is substantial, nearly three lake volumes per year.

Lakes in the Grassy Creek system above Lake Tippecanoe have uniformly high Indiana TSI scores ranging from 26 to 39 (Table 22). Lower Secchi disk transparencies and higher total phosphorus concentrations confirm that these lakes are generally more productive than those in the upper Tippecanoe River system. Due to the great amount of water flowing through these lakes, the total load of phosphorus and organic nitrogen reaching Lake Tippecanoe from the Grassy Creek system is significant (see Figure 16).

This analysis suggests an approach toward management of Lake Tippecanoe. While it is important to control erosion and nutrient losses from lands immediately adjacent to the lake which drain via Indian Creek, Hannabe Walker Ditch, and Long Ditch, comprehensive management of Lake Tippecanoe must also consider management in the upstream lakes and tributaries which can prevent downstream transport of sediment and nutrients.

The Tippecanoe River and Grassy Creek contribute the most nutrients to the Lake James and Lake Tippecanoe. However, due to their large sizes (51 and 52 square miles (82-84 km^2) of drainage respectively) direct control of nutrients within the stream channel is not possible within several miles of the lake. Kuhn Ditch, Hannabe-Walker Ditch, and Indian Creek are also major nutrient, sediment and coliform contributors but are small enough to warrant attempts at controlling their output of nutrients into Lake James and Lake Tippecanoe.

The Tippecanoe River inputs are best addressed within upstream tributaries and lakes. Crooked Lake, at the headwaters of the river, is currently in the construction phase of an IDNR sponsored Lake and River Enhancement initiative. Kuhn Ditch, a major tributary, is recommended for treatment. Big Lake has had a preliminary study completed by the IDNR with management recommendations at controlling nutrient inputs from septic systems. Support of projects on these lakes and others will contribute to cleaner water entering Lake Tippecanoe.

Table 21. Indiana Trophic Score Index values for Lakes on the Tippecanoe River

LAKE	YEAR SAMPLED	TOTAL PHOSPHORUS (mg/L)	SECCHI DISK TRANSPARENCY (m)	INDIANA TROPHIC STATE INDEX SCORE
Crooked	1994	0.142	4.5	11
Big	1994	0.166	2.8	27
Smally	1993	0.584	1.3	40
Baugher	1994	0.412	1.2	42
Wilmot Pond	1994	0.097	1.8	12
The Backwaters	1994	0.068	1.0	17
Webster	1994	0.15	1.3	25
James	1996	0.096	2.2	30
Tippecanoe	1996	0.037	1.8	20

Table 22. Indiana Trophic Score Index values for Lakes on Grassy Creek

LAKE	YEAR SAMPLED	TOTAL PHOSPHORUS (mg/L)	SECCHI DISK TRANSPARENCY (m)	INDIANA TROPHIC STATE INDEX SCORE
Robinson	1990	0.100	0.7	27
Big Barbee	1994	0.272	1.05	39
Little Barbee	1994	0.373	0.9	38
Sawmill	1994	0.192	0.8	26
Tippecanoe	1996	0.037	1.8	20

Grassy Creek originates in the agricultural fields to the southeast of Lake Tippecanoe. Much of the watershed has been drained by ditching and thus water enters the lake chain including Ridinger and Barbee Lakes heavily laden with eroded soil and nutrients immediately after thunderstorms. An earlier study by the U. S. Army Corps of Engineers (1995) summarized that building detention structures on several of the primary ditches would alleviate much of the flooding and nutrient loading on the Barbee chain and thus Lake Tippecanoe (Figure 27). The District Conservationist with the Kosiusko County Natural Resource Conservation Service, Sam St. Claire, suggested that considerable erosion control work need to be completed in the upper reaches of Grassy Creek. Mr. St. Claire urged interested members of Lake Associations to join specific watershed task forces with the SWCD. These task forces identify specific erosion areas with the help of SWCD staff and then assist landowners that are willing to implement conservation practices.

Kuhn Ditch has a high suspended sediment load as well as elevated levels of fecal coliform bacteria, nitrogen and phosphorus. Kuhn Ditch can be treated using a typical stormwater filter within the confines of the existing drainage easement (Figure 26-30). The vegetated storm water filter is designed to remove 75% of total suspended solids, 45% of total phosphorus, and 25% of total nitrogen during a one year 24 hour storm event (87 cfs). Table 22 outlines estimated construction costs for a filter on Kuhn Ditch.

Long Ditch or Rich Creek had high levels of suspended sediment, fecal coliform and nutrients, however, much of the water of the creek is dispersed into a wooded wetland before entering the lake. It is suggested that the county SWCD continue working with the major landowners of this watershed to control erosion of the active pasture and agricultural fields. No structures or sediment traps should be necessary once the land surface has been protected from erosion.

Hannabe-Walker Ditch has a high suspended sediment and phosphorus load. Sediment traps could be constructed with an optional treatment wetland to handle a one year 24 hour storm event and remove 75% of suspended sediment, 45% of total phosphorus and 25% of total nitrogen. Figures 31-35 are conceptual plans for these structures. Table 23 outlines estimated construction costs for a filter and sediment trap on Hannabe-Walker Ditch. If a sediment trap and filter is constructed, annual cleaning of the trap will be necessary. Additionally, the Lake Association should consider dredging the outlet of the ditch to remove the nutrient laden sediments from the shallow water at the mouth. Removing these sediments would reduce the exposure of the water column to the phosphorus and nitrogen adsorbed onto the sediment. Disposal methods and cost estimates for dredging at this location have been completed earlier and were estimated at approximately $59,000.

Indian Creek has elevated levels of fecal coliform bacteria and abnormally high storm water volume and velocity causing erosion of embankments and subsequent above average sediment loads. Control of storm water from drainage off the Tippecanoe Country Club and agricultural fields to the north would resolve both problems. A series of detention structures has been conceptually designed to retain water for 48 hours during a five year event. This retention time causes the coliform bacteria and associated pathogens to perish and allows a more controlled flow of water into the natural channel (Figures 36-39). Table 24 has estimated construction costs for a series of detention structures on Indian Creek.

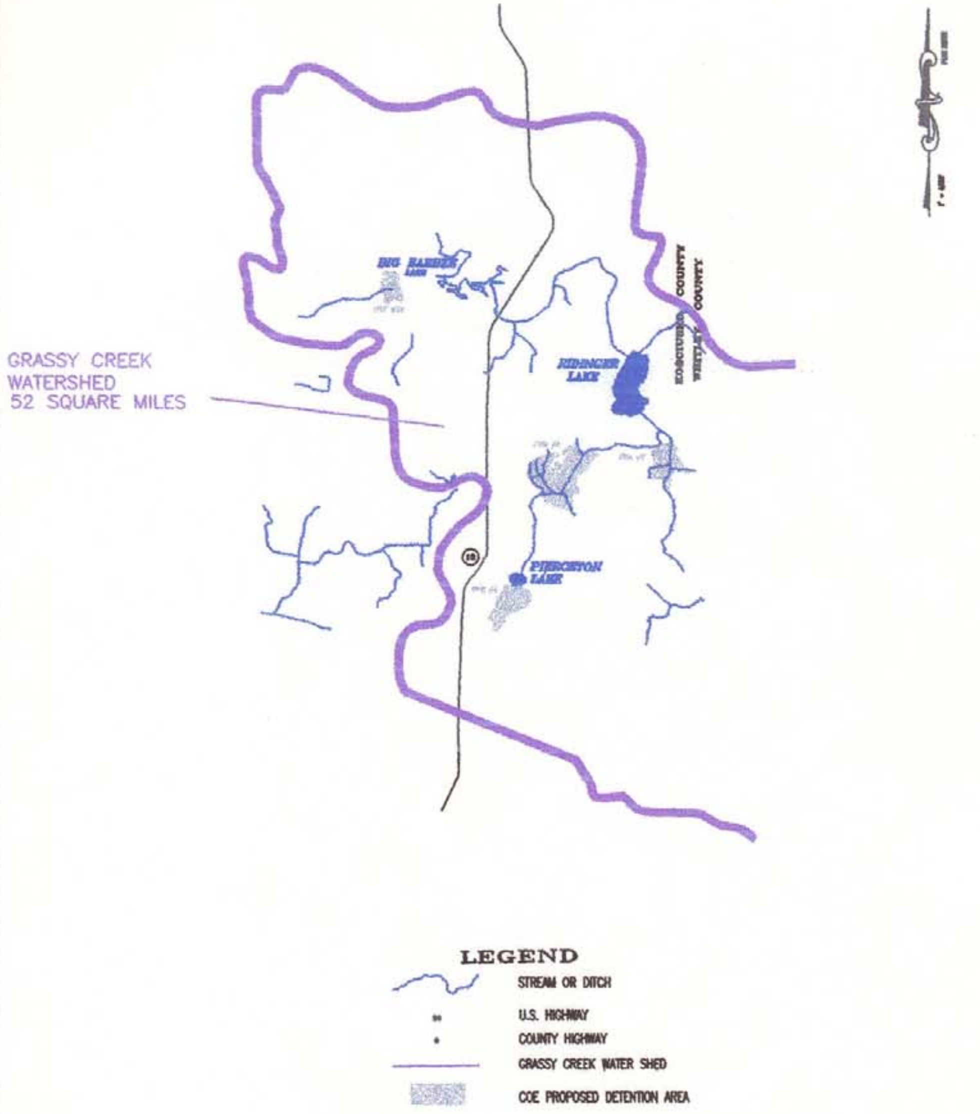
SUMMARY

The results of this study suggest phosphorus loading from external sources and in-lake sediments is resulting in the eutrophication of Lake Tippecanoe. A 20 percent reduction in phosphorus loading is required to bring the lake back to an equilibrium where phosphorus export equals import. There is not a single source of phosphorus or associated sediment that can account for a 20% reduction, which means several methods must be addressed.

By containing sediments and their associated nutrients in the secondary tributaries of Kuhn and Hannabe-Walker Ditch, and then removing or stabilizing phosphorus contaminated sediments in shallow areas of the lakes much of the needed reduction can occur. Sediment traps, wetland filters and detention structures will aid in removing nutrients and sediments from the ditches, however, long term stabilization comes from good conservation practices like conserving wetland areas, grassed waterways, filter strips, and no-till farming. Just as importantly, is stabilizing or removing nutrient enriched sediments already in the lake. Stabilization of sediments with aquatic vegetation and observation of no-wake zones is the most economical way to control nutrients in the lake bottom. Where that is not practical, removal of sediments may be necessary.

Support of SWCD programs in the upper watershed of Grassy Creek and partnering with the Ridinger and Barbee Lake Associations on their lake enhancement activities will bring about a long term reduction of nutrients from Grassy Creek. In addition, detention of water in the headwaters of Indian Creek would be cost effective for eliminating a major source of fecal coliform bacteria.

This study has diagnosed the current health of the lake and potential sources of nutrients that need to be addressed. To move forward, the Lake Association or other representative body needs to apply for Lake and River Enhancement funding from the IDNR for a feasibility and design phase or work with the SWCD, Drainage Board and Health Department to directly implement some or all of the recommended actions. Most of the recommended action within existing waterbodies will require landowner cooperation and regulatory approvals. The final design and permitting of future structures will be expedited by early coordination with affected landowners and regulatory personnel.

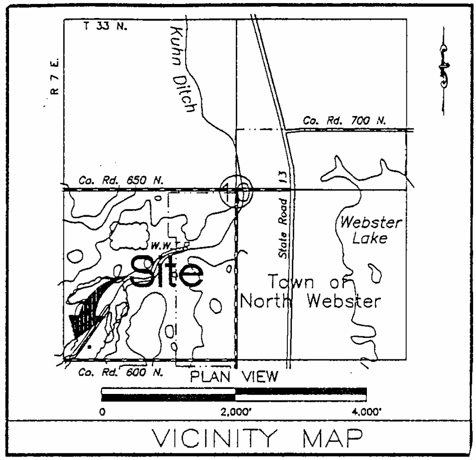


* U.S. Army Corps of Engineers, 1995. Upper Tippecanoe River Basin Kosciusko County, Indiana Interim Reconnaissance Report. Louisville, Kentucky.

FIGURE 27.
LAKE TIPPECANOE FEASIBILITY STUDY
CORPS OF ENGINEERS PROPOSED DETENTION AREAS* IN GRASSY CREEK WATERSHED

J.F. New & Associates, Inc.

Kuhn Ditch Watershed Treatment System



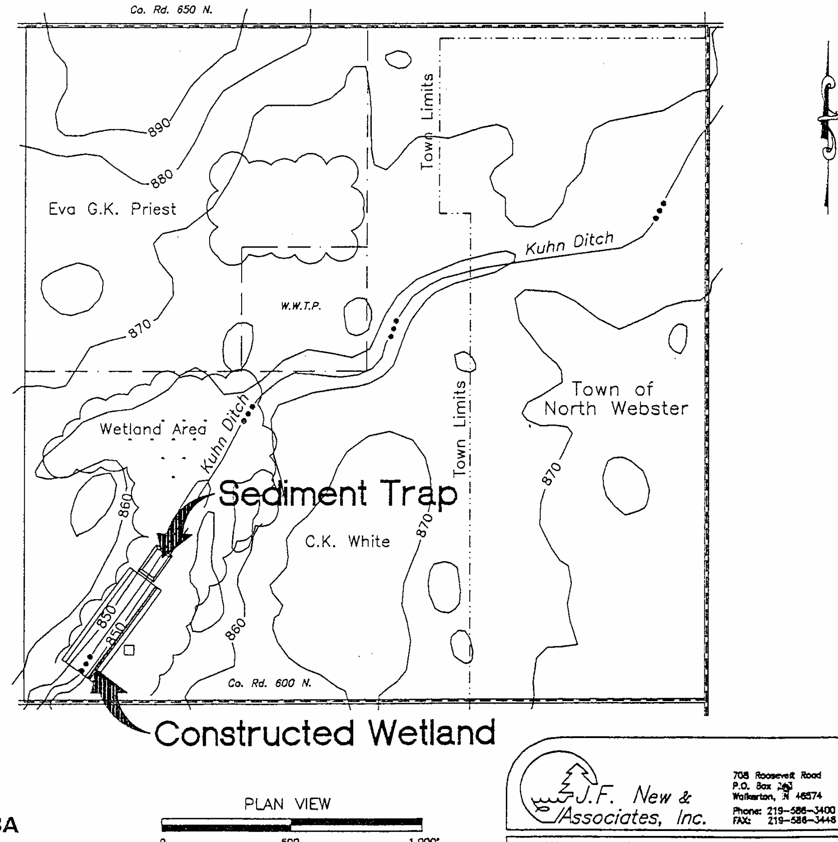


FIGURE 28A
KUHN DITCH
LOCATION MAP

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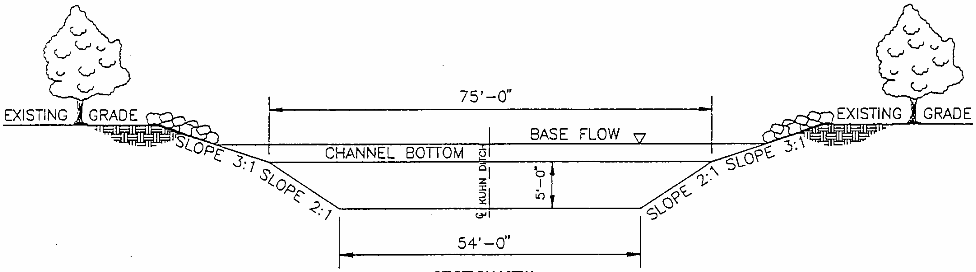
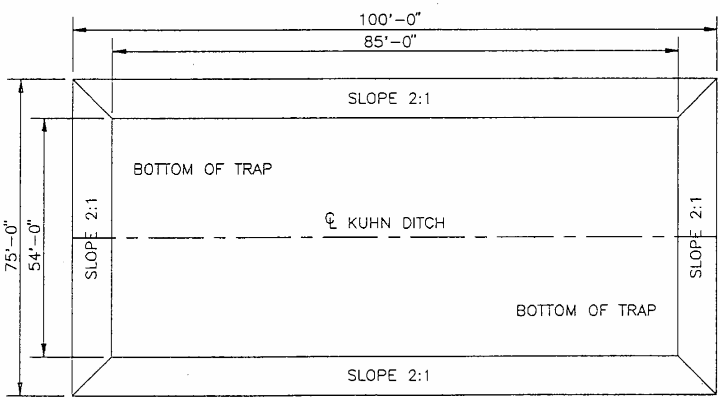
Kuhn Ditch Watershed Project Sediment Trap



SECTION VIEW

SEDIMENT TRAP
NOT TO SCALE



PLAN VIEW

SEDIMENT TRAP
NOT TO SCALE

FIGURE 28B
KUHN DITCH
SEDIMENT TRAP DETAIL

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Kuhn Ditch Watershed Project Constructed Wetland

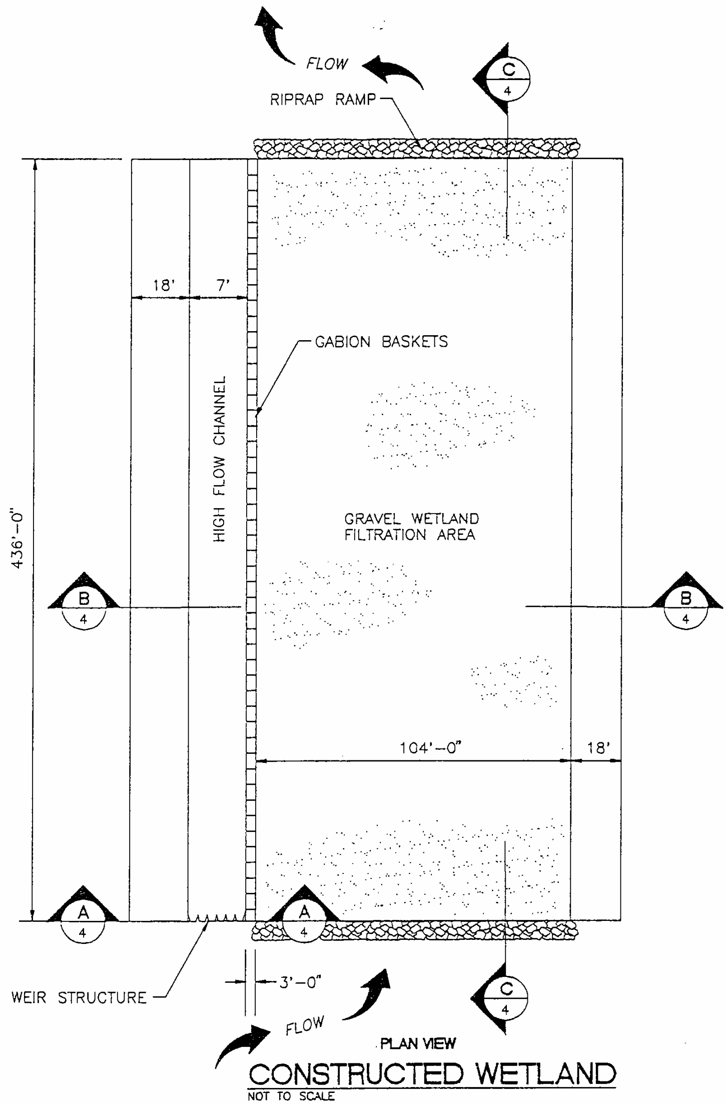

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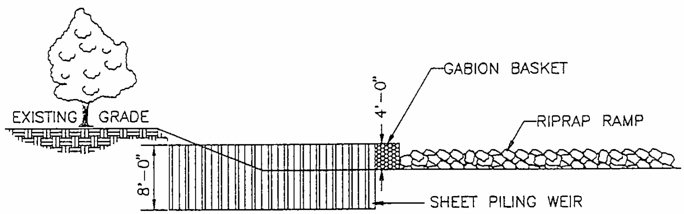
FIGURE 28C
KUHN DITCH
CONSTRUCTED WETLAND

Kuhn Ditch Watershed
Project Constructed Wetland Details



SECTION - A
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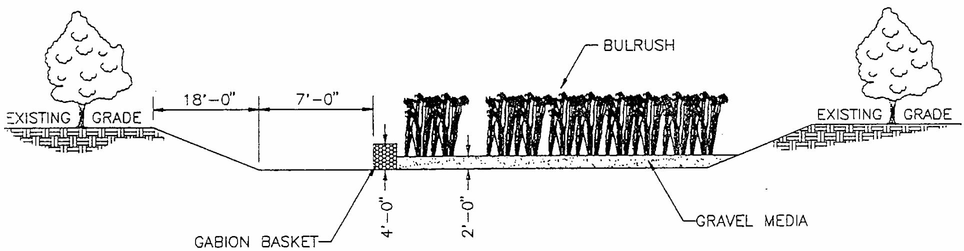

SECTION - B
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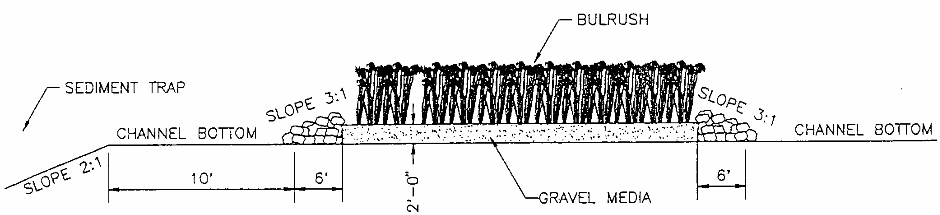

SECTION - C
NOT TO SCALE

FIGURE 28D
KUHN DITCH
CONSTRUCTED WETLAND DETAIL

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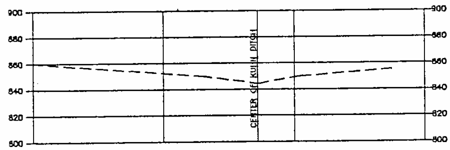
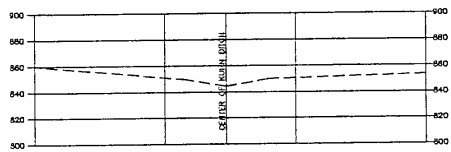
Kuhn Ditch Watershed
Project Cross Sections



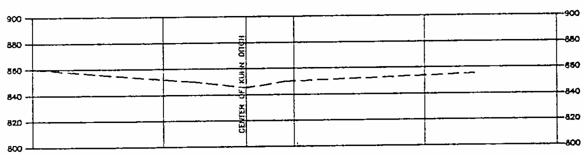
SECTION A

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL



SECTION B

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL



SECTION C

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL

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FIGURE 28E
KUHN DITCH
CROSS SECTIONS

Table 22. Cost Estimates of Kuhn Ditch Treatment Wetland For Lake Tippecanoe Nutrient Control

	Including Sediment Trap				NOT Including Sediment Trap			
ITEM	**No. of UNITS**	**UNIT COST**		**TOTAL**	**No. of UNITS**	**UNIT COST**		**TOTAL**
Earthwork	10698 c	$4.5	/cy	$48,141	7498 c	$4.5	/c	$33,741
Filter Gravel	3359 c	$10	/cy	$33,590	3359 c	$10	/c	$33,590
RipRap	93 c	$35	/cy	$3,255	49 c	$35	/c	$1,715
Gabions	436 ft	$71	/sf	$30,956	436 ft	$71	/s	$30,956
Sheet Piling	240 sf	$20	/sf	$4,800	240 sf	$20	/s	$4,800
Plants (2'x2')	22672 ls	$22,672	ls	$22,672	22672 ls	$22,672	ls	$22,672
Erosion Control	2000 ls	$2,000	ls	$2,000	2000 ls	$2,000	ls	$2,000
Clearing	1500 ls	$1,500	ls	$1,500	1500 ls	$1,500	ls	$1,500
Mobilization	1500 ls	$1,500	ls	$1,500	1500 ls	$1,500	ls	$1,500
Stream Diversion	4814 ls	$4,814	ls	$4,814	3374 ls	$3,374	ls	$3,374
Total Construction Cost:				**$153,228**				**$135,848**
Construction Engine	4000 ls	$4,000	ls	$4,000	4000 ls	$4,000	ls	$4,000
Inspection (10 days):	5200 ls	$5,200	ls	$5,200	5200 ls	$5,200	ls	$5,200
Administration:	3000 ls	$3,000	ls	$3,000	3000 ls	$3,000	ls	$3,000
Total Construction Phase Cost:				**$165,428**				**$148,048**

Hannabe-Walker Watershed Treatment System

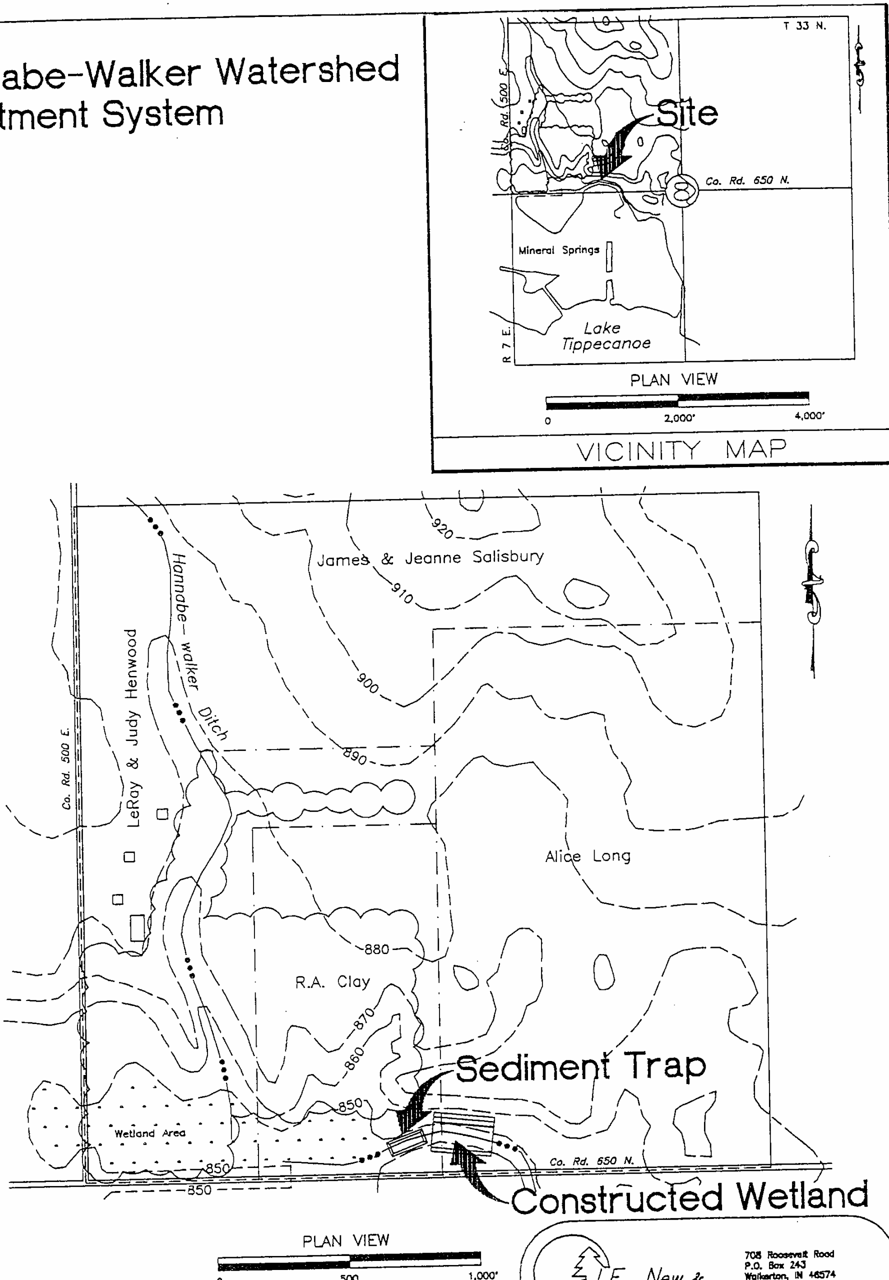

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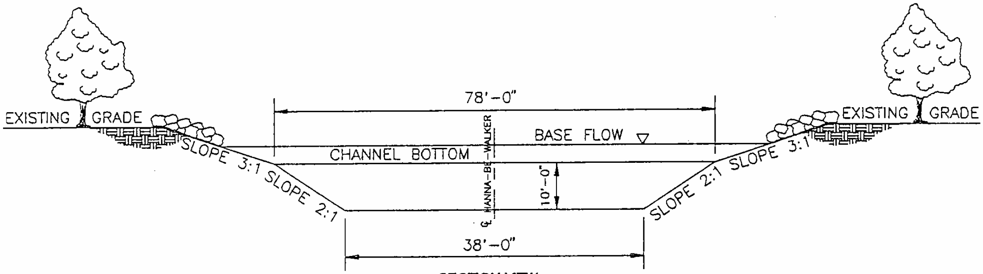
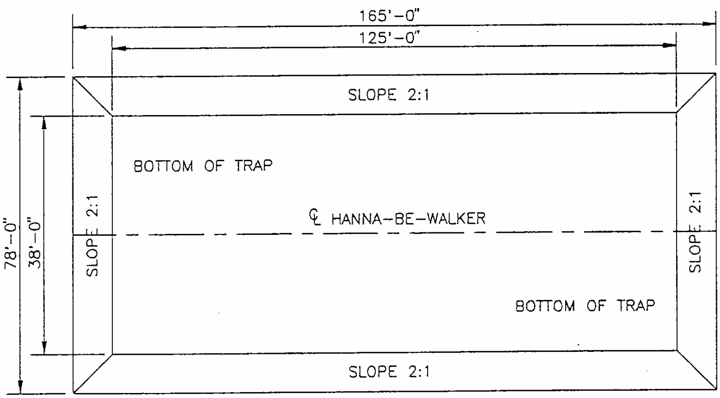
FIGURE 29A
HANNABE-WALKER
LOCATION MAP

Hannabe-Walker Watershed Project Sediment Trap



SECTION VIEW

SEDIMENT TRAP
NOT TO SCALE



PLAN VIEW

SEDIMENT TRAP
NOT TO SCALE

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FIGURE 29B
HANNABE-WALKER
SEDIMENT TRAP DETAIL

Hannabe-Walker Watershed Project Constructed Wetland

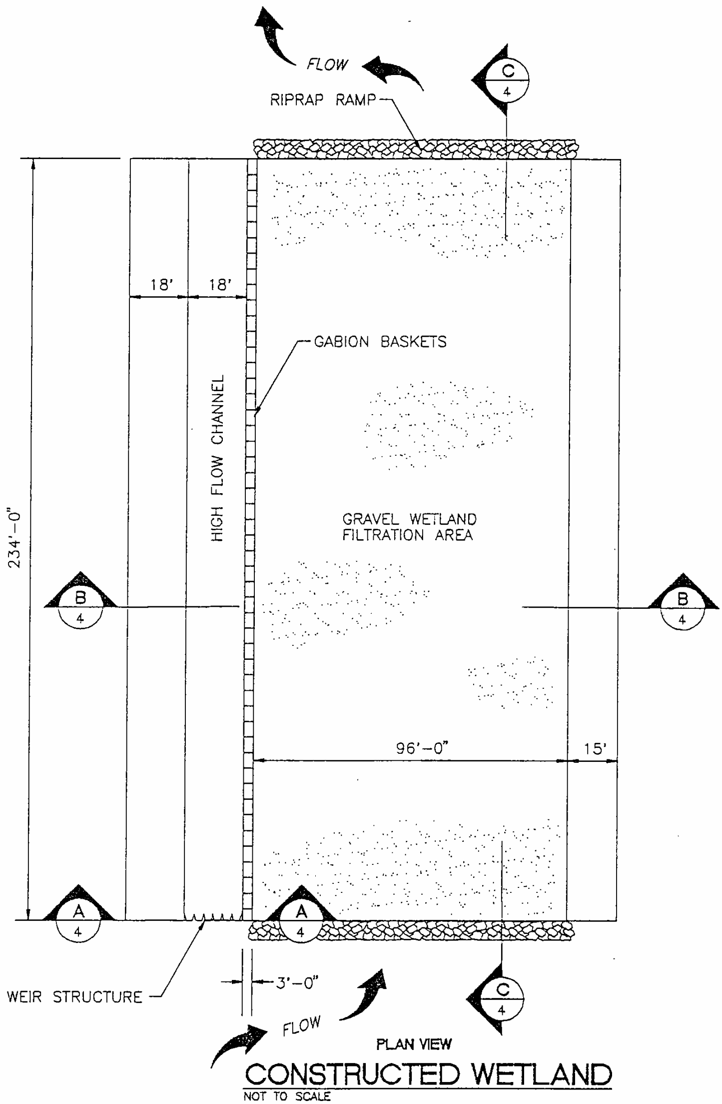

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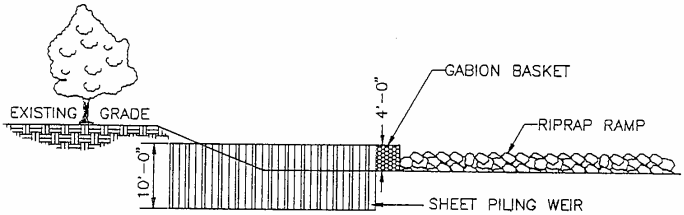
FIGURE 29C
HANNABE-WALKER
CONSTRUCTED WETLAND

Hannabe-Walker Watershed
Project Constructed Wetland Details



SECTION - A
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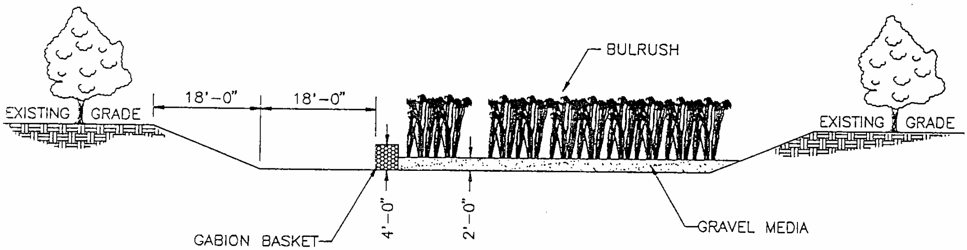

SECTION - B
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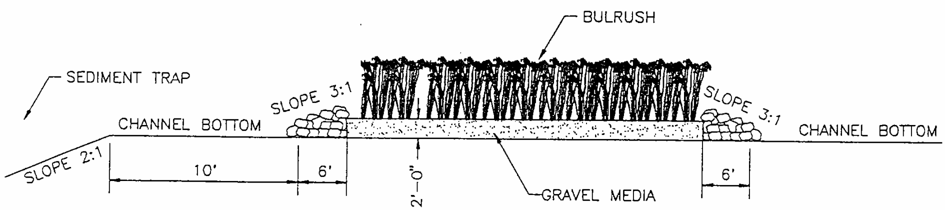

SECTION - C
NOT TO SCALE

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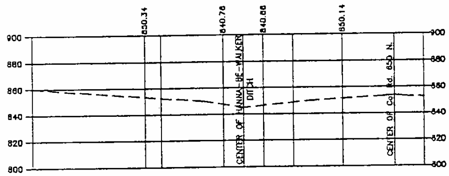
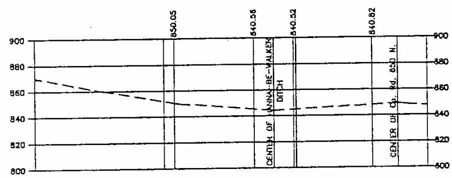
FIGURE 29D
HANNABE-WALKER
CONSTRUCTED WETLAND DETAIL

Hannabe-Walker Watershed
Project Cross Sections



SECTION A

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL



SECTION B

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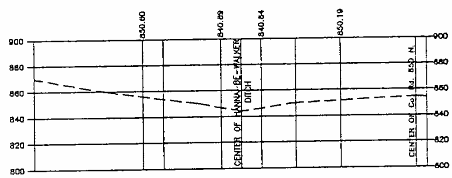

SECTION C

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL

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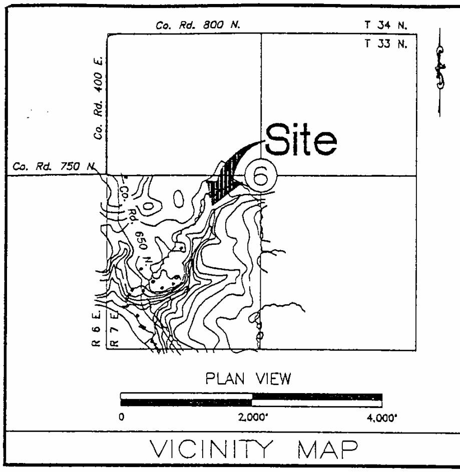
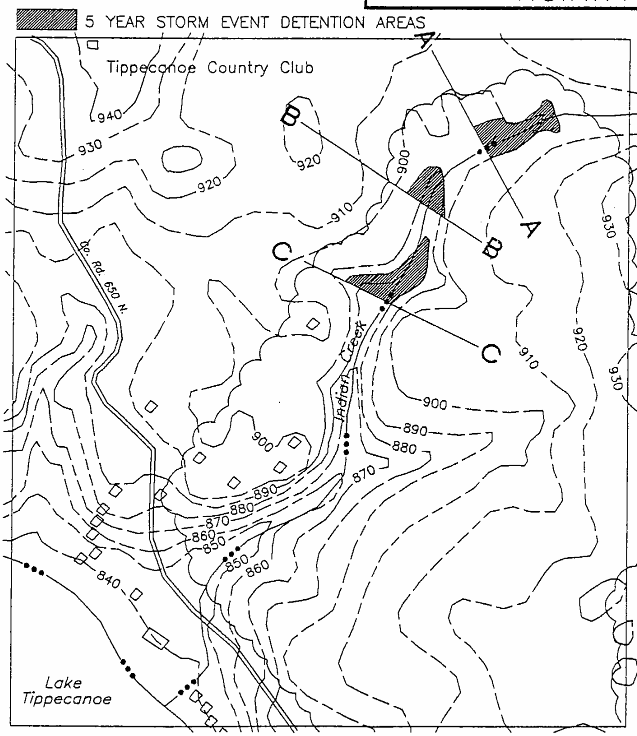
FIGURE 29E
HANNABE-WALKER
CROSS SECTIONS

Table 23. Cost Estimates of Hannabe-Walker Suspended Sediment Removal Structures

ITEM	No. of UNITS	UNIT COST	TOTAL
Sediment Trap Excavation	7367 cy	$5 /cy	$36,835.00
Wetland Filter Excavation	7293 cy	$5 /cy	$36,465.00
Wetland Gravel	1638 cy	$10 /cy	$16,380.00
Bulrush Planting	10296 sf	$2 /sf	$20,592.00
Weir Piling	270 sf	$20 /sf	$5,400.00
3'X6' Gabions	234 lf	$71 /lf	$16,614.00
Rip Rap	42 cy	$35 /lf	$1,470.00
Contingency		15%	$20,063.40
Total Construction Cost:			**$153,819.40**

Indian Creek Watershed Detention System





PLAN VIEW

0 500 1,000'

FIGURE 30A
INDIAN CREEK
LOCATION MAP

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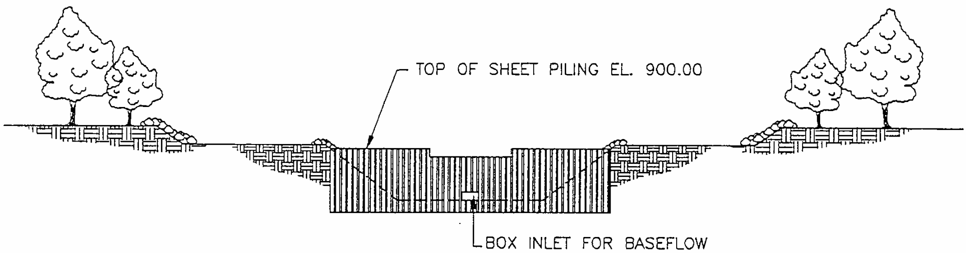
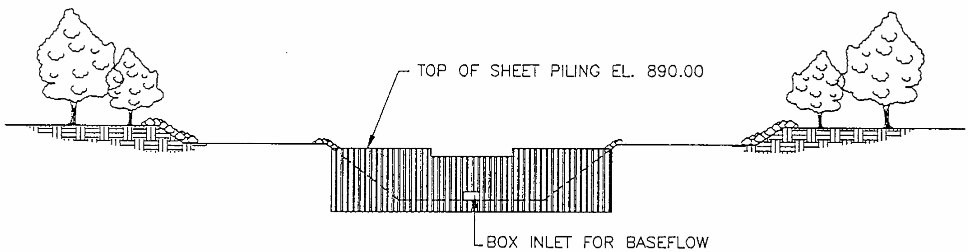
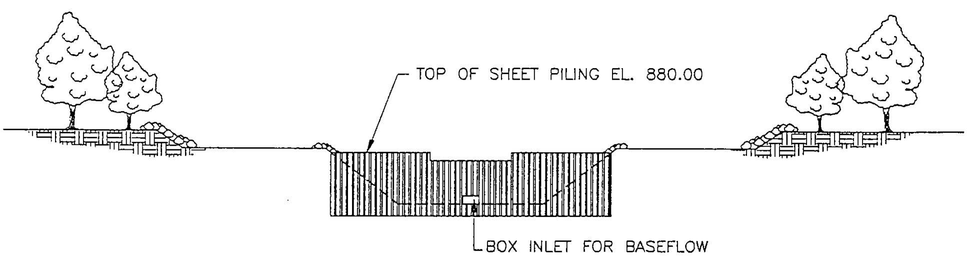
Indian Creek Watershed Detention System



SHEET PILING DETAIL - A
NO SCALE



SHEET PILING DETAIL - B
NO SCALE



SHEET PILING DETAIL - C
NO SCALE

FIGURE 30B
INDIAN CREEK
DETENTION SYSTEM

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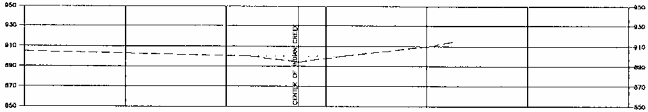
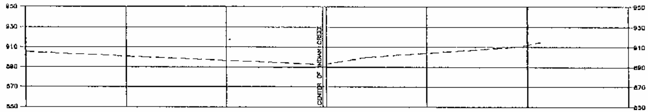


SECTION A

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL



SECTION B

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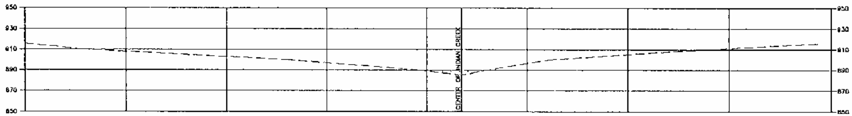
1" = 100' HORIZONTAL



SECTION C

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL

FIGURE 30C
INDIAN CREEK
CROSS SECTIONS A, B, C

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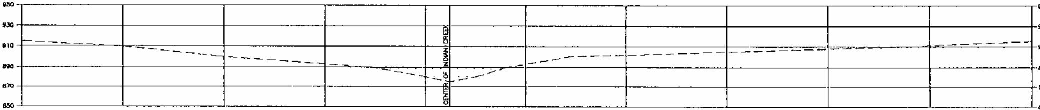

SECTION D

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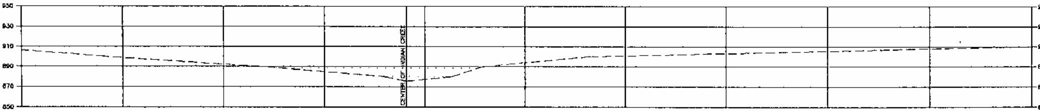
1" = 100' HORIZONTAL



SECTION E

SCALE: 1" = 100' VERTICAL
1" = 100' HORIZONTAL

FIGURE 30D
INDIAN CREEK
CROSS SECTIONS D, E

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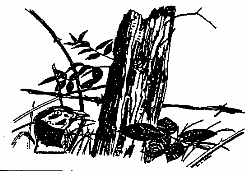
APPENDIX A

U.S.D.A. CONSERVATION PROGRAMS

FNR 157



HOOSIER FARMLAND WILDLIFE NOTES

Fostering Wildlife in Agriculture Vol. 3 No. 1

New CRP Provisions Provide Good Return on Marginal Acres While Managing for Wildlife

Brian K. Miller and Clark D. McCreedy

Forestry and Natural Resources Cooperative Extension Service Purdue University

The 1996 Farm Bill has restructured CRP and other conservation programs to target acres and practices that provide the greatest environmental benefits for the dollars spent. There are two ways to enter CRP:

1. During a continuous sign-up period which allows landowners to sign-up at any time as long as the land is eligible and will be placed in filterstrips, riparian buffers, grassed waterways, field windbreaks, or shallow water areas for wildlife.

2. A CRP program similar to the original CRP which can only be entered during limited sign-up periods.

Continuous CRP does not undergo a competitive bid process like the sign-up CRP. It provides for a 20% incentive payment to be added the the maximum rental rate determined for the acreage in your County. This option definitely merits consideration as it allows you to receive an income on marginal lands that may equal or even exceed cash rental rates that could be obtained on this acreage. Instead of waiting until the next general sign-up period, producers are now able to enroll qualifying acres at any time. This will give farmers more options for better land management as they can plan their activities for the coming crop year at any time and do not have to wait for signup periods to be announced.

If you are interested in entering into the CRP program and your acreage or selected practices do not qualify for continuous sign-up, the chances for getting your offer accepted during regular sign-up periods can be increased by choosing native species for cover plantings and selecting practices and planting designs which enhance wildlife habitat. These practices are assigned higher point values which are used to caluculate your Environmental Benefits Index (the rating score used to select the offers with the highest environmental return). Differences between the two enrollment methods are detailed in Table 1.

Eligible Cropland:

Land must have been planted or considered planted to an agricultural commodity two of the five most recent crop years and must be capable of being planted to an agricultural commodity. Marginal pasture land is also eligible if it will be devoted to a riparian buffer that will be planted to trees. Eligible cropland must meet one of the following criteria:

- an erosion index (EI) of 8 or higher or be considered as "highly erodible"
- be considered a cropped wetland
- be devoted to one of the practices required for continuous CRP
- Be subject to scour erosion
- Be located in a national or state CRP Conservation Priority Area
- Be cropland associated with or surrounding non-cropped wetlands

Table 1. Summary of options and practices for CRP enrollment under continuous enrollment and CRP enrollment restricted to a sign-up period.

	Continuous CRP	**Sign-up CRP**
Sign-up Period	Anytime (began Sept. 4, 1996)	March 3, 1997 - March 28, 1997 (there may be future sign-ups)
Eligible Practices	Filter strips - CP21* Riparian buffers - CP22 Field windbreaks - CP5 Grassed waterways - CP8 Shallow water areas for wildlife - CP9 *Conservation Practice	Permanent intro. grasses and legumes - CP1 Permanent native grasses - CP2 Tree planting in wildlife shrubs - CP3 Hardwood tree planting - CP3A Permanent wildlife habitat (including corridors) CP 4 Vegetative cover (grass already est.) - CP10 Vegetative cover (trees already est.) - CP11 Wildlife food plots - CP12 Ally cropping - CP19 Wetland restoration - CP23 Higher ranking values can be obtained in these practices by choosing planting mixtures and designs best suited for wildlife.
Length of Contract	non-tree acres - 10 years practices planted to trees may be entered up to 15 years	non-tree acres - 10 years practices planted to trees may be entered up to 15 years
Competitive Bid Process	automatically accepted - no competitive bid process	Must compete nationally. Environmental Benefits Index (EBI) based on price and benefits to wildlife, erosion control, and water quality.
Payment Rate	Maximum posted at FSA office + 20% incentive payment + $5 / acre maintenance allowance	Maximum posted at FSA office + $5 / acre maintenance allowance
Cost-share Payment for Practice	50 %	50 %
Contract Effective Date	The first day of the month following the month of approval	Participant's option: October 1, 1997, or October 1, 1998

Rental Rate Determination

The rental rate will be based on county average dryland cash or cash-rent equivalent rental rates adjusted for site-specific, soils-based productivity factors. An additional allowance of up to $5 per acre can be made as an incentive to perform certain maintenance obligations. Under continuous CRP enrollment, an additional 20% of the cash rental rate is available as an incentive payment to enter into the practice. Cost-share assistance of 50% will also be provided to establish conservation practices.

Renewal of Existing Contracts

Landowners who want to continue participation in CRP once existing contracts expire, must re-offer that land either for the continuous or general sign-up process. Acreage subject to expiring contracts, if re-offered, must compete with all other acreage being offered at that time. Landowners will be required to sign new contracts for all acreage accepted. On September 30, 1997, CRP contracts for 24 million acres will expire. This acreage is then available for new contracts to be entered into the program. The total number of acres that can be in CRP nationally at any one time is 36.4 million acres.

Selection Criteria for Sign-Up CRP

All eligible CRP offers will be ranked using an Environmental Benefits Index (EBI). This index ranks offers based on the environmental benefits they provide and ensures that only the most environmentally sensitive lands are selected. Ranking factors include:

- benefits to wildlife
- on-farm benefits from reduced erosion
- water quality benefits from reduced erosion runoff and leaching
- air quality benefits from reduced wind erosion
- long-term retention benefits beyond the CRP period
- cost per acre for enrollment
- location in Conservation Priority Areas (Benton, Jasper, Newton, Pulaski, Starke counties and Princeton Township in White county, in addition to the Salt Creek watershed in portions of Brown, Jackson, and Monroe counties and the thirteen counties which drain to the Great Lakes [see Figure 1 on last page]. All croplands located in these areas are elgible and do not have to meet the erosion criteria).

Producers should know in advance what the maximum rental rate will be for their county and can bid whatever they choose as long as it does not exceed the maximum rate. Landowners can propose less than the maximum rental rate to increase the likelihood of bid acceptance through the competitive environmental benefits indexing process.

Additional Programs

There are a variety of additional practices and programs that can be added to CRP acres to enhance wildlife habitat and reduce costs or increase cost share potential, thus making wildlife management on marginal acres even more affordable. The programs and responsible agencies or organizations are detailed below. If you are interested in CRP and any of these additional programs, your first visit should be to your county FSA office. They can put you in touch with the other agencies or organizations listed below.

1. Additional cost-share funds may be available from the Indiana Department of Natural Resources (IDNR) Division of Fish and Wildlife for purchasing shrubs, trees, seed, fertilizer, labor, etc. not covered by the CRP cost share as long as costs do not exceed $100/ acre and/or 100% of the total cost of establishing the practice is not exceeded. *Contact your IDNR District Wildlife Biologist.*

2. CRP acres can also be entered into the Classified Wildlife Habitat Act, which reduces your tax assessment to $1 per acre per year. You need a minimum of 15 contiguous acres to enroll and no more than 10 acres can be in trees. You must pay for the original survey on these acres and are responsible for up to 10 years of back taxes if you remove this acreage from the Classified Wildlife Habitat program. *Contact your IDNR District Wildlife Biologist.*

3. The U.S. Fish and Wildlife Service's Partners For Wildlife Program may provide cost share and technical assistance for wetland restoration, bottomland hardwood plantings, and prairie grass establishment on or adjacent to CRP acres. *Contact the USFWS at (812) 334-4261 for details.*

4. Conservation organizations such as Pheasants Forever and Quail Unlimited may be able to help plant and provide seed, shrubs, drills, and technical assistance for establishing some of these practices. Services may vary by organization and chapter. Contact information and a description of technical assistance available to the landowner from such organizations can be obtained from the Purdue University Extension Service by requesting the publication: *FNR-87, Forestry and Wildlife Management Assistance Available to Indiana Landowners: Providers, Organizations, and Programs.*

5. Field margins that are incidental to the planting of crops are eligible for CRP enrollment.

If you miss this sign-up period there may or may not be future sign-ups. In addition, two new programs, Wildlife Habitat Incentives Program (WHIP) and the Environmental Quality Incentives Program (EQIP), will soon be announced which also provide cost share funds for wildlife management on your property. These two programs will be featured in future issues of *Hoosier Farmland Wildlife Notes.*

Figure 1. State and National Conservation Priority Areas in Indiana (the 13 counties in the Great Lakes watershed are National Conservation Priority Areas). All croplands located in these areas are eligible for CRP and do not have to meet erosion criteria.

CRP Facts

Studies have documented tremendous wildlife and water quality benefits that resulted from the original CRP program. CRP was originally designed primarily to reduce soil erosion. Since its inception, CRP has reduced annual soil erosion by up to 25% (saving 694 million tons of top soil per year). In addition, almost 2 million acres of wildlife habitat has been planted and 14,000 acres of wetlands have been developed. Grassland wildlife populations have increased and the 1996 fall flight record of 90-million ducks was attributed in part to the increased habitat developed in production and flyway areas.

USDA

INDIANA DIVISION OF FISH & WILDLIFE

"Hoosier Farmland Wildlife Notes" is a joint effort of FSA, IDNR Div. of Fish and Wildlife, NRCS, Purdue University Dept. of Forestry & Natural Resources, and U.S. Fish and Wildlife Service. Steering Committee: Ron Birt, Jeff Kiefer, Clark McCreedy, Pete Meyer, Brian Miller, Dave Stratman. Cooperative Extension work in Agriculture and Home Economics, State of Indiana, Purdue University, and U.S. Department of Agriculture cooperating; H. A. Wadsworth, Director, West Lafayette, IN. Issued in furtherance of the acts of May 8 and June 30, 1914. The Purdue University Cooperative Extension Service is an equal opportunity/equal access institution. WWW address: http://hermes.ecn.purdue.edu:8001/http_dir/acad/agr/extn/agr/acspub/acspub.html
2/97 (130m)

1996 Farm Bill

Farm Bill Q&A's For Indiana - #1

March 28, 1997

USDA United States Department of Agriculture
Natural Resources Conservation Service
Farm Services Agency
Purdue Cooperative Extension Service
Indianapolis, Indiana

This Farm Bill Question and Answer sheet is brought to you by USDA Agencies to help you use best conservation efforts on your farm. The fact-sheet provides a forum for farmers and consumers to ask top questions about the 1996 Farm Bill. You can ask specific questions by contacting your NRCS, FSA or Purdue Cooperative Extension Service county offices.

This week's Q&A focus on EQIP.

Q: What is EQIP?

A: The Environmental Quality Incentive Program is a new U.S. Department of Agriculture program under the 1996 Farm Bill that provides technical, financial and educational assistance to farmers and ranchers to address significant natural resources concerns and objectives. EQIP replaces four previous programs: the Agricultural Conservation Program (ACP), Water Quality Incentive Program (WQIP), Great Plains Conservation Program (GPCP), and the Colorado River Basin Salinity Control Program (CRBSCP).

Q: What's the difference between EQIP and ACP?

A. ACP gave incentive payments to farmers for installing individual conservation practices, or systems of practices. The funding for ACP was generally a single year comittment. In EQIP, producers enter into 5-10 year contracts based on resource management systems they develop with assistance from NRCS (or other public or private natural resource professionals) and approved by the local conservation district. The plan is used to establish an EQIP contract. The program requires producers to implement conservation practices to address the important natural resources concerns that are identified in the resource management plan, such as excessive soil erosion and water quality degradation on a farm or tract.

Q: When can I sign up for EQIP?

A: We won't know that answer until final rules are announced by the Secretary of Agriculture, Dan Glickman. Our best estimate will be in mid- to late April. Please check with your NRCS, FSA, or Extension office at that time.

Q: How much money will be available?

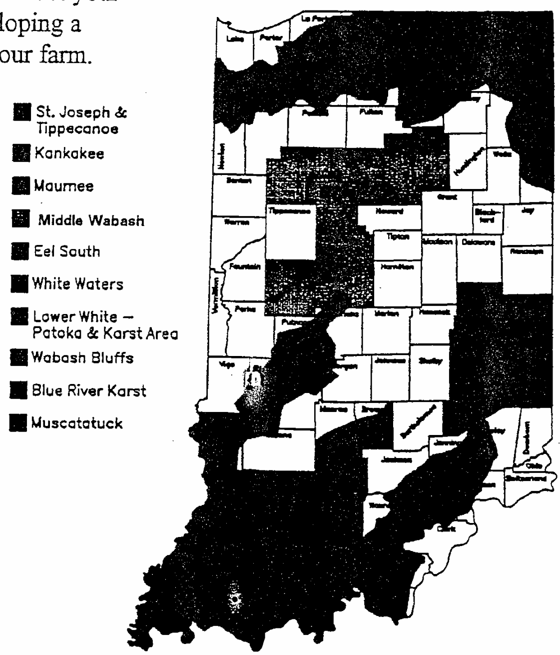
A: For FY '97, $2,574,000 has been allocated for Indiana (at least 65 percent must be allocated to the priority areas, which cover or touch 67 of Indiana's 92 counties; 35 percent can be allocated to counties where no priority area has been established yet. For priority areas contact your county offices.) The maximum a farmer may receive in a given year is $10,000 depending on limitations.

Q: When will EQIP money be available?
A: FY '97 funds must be tied to resource management systems by Sept. 30, or the funds will go back to Washington for redistribution. Actual payments to farmers can begin after Oct. 1 as systems and practices are completed. In following years, money can be paid to farmers as systems and practices are completed.

Q: How will I qualify for EQIP?
A: When final rules are announced, more details will be forwarded to county offices. But the new Farm Bill focuses on resource management systems. You can contact your NRCS office now to begin developing a resource management plan for your farm. Based on what we know now, your plan will be ranked in comparison with others in your priority area.

Q: How does EQIP fit into my conservation system?
A: EQIP is one tool in the Farm Bill "toolbox for conservation". Other tools include CRP, FIP, WHIP, etc.

Approved Priority Areas March 1997



NATIONAL CONSERVATION BUFFER INITIATIVE / CONSERVATION RESERVE PROGRAM CONTINUOUS SIGN-UP

Guidance Document

This document has been prepared to support the National Conservation Buffer Initiative, with particular emphasis on how the initiative relates to the continuous sign-up provision of the Conservation Reserve Program (CRP). This guidance document addresses only the use of buffers as allowed under this provision of CRP.

The purpose of this initiative is to encourage the use of conservation buffers to accomplish a variety of natural resource conservation purposes--prevent soil erosion, protect and enhance soil quality, prevent air and water pollution, increase wildlife habitat, and enhance landscape diversity. The wise use of buffers allows landowners to keep their best land in crop production, but also to make good use of marginal land. This initiative is being promoted by several USDA agencies--the Natural Resources Conservation Service; Farm Service Agency; Cooperative State Research, Education, and Extension Service; and Forest Service--and many other partner agencies and organizations.

A significant tool to help accomplish the objectives of the National Conservation Buffer Initiative is the new continuous sign-up provision of CRP. This provision allows a landowner to establish certain conservation buffer practices on cropland and marginal pastureland and enroll the land in CRP without having to go through the normal CRP competitive-offer process. This program can be used to help landowners leave existing vegetation for filter strips, riparian forest buffers, contour buffer strips, grassed waterways, and other buffer practices as land in expiring CRP contracts is returned to crop production. There are also other federal, state, local, and private programs that can help landowners implement buffer practices, including the Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentives Program (WHIP), and Wetlands Reserve Program (WRP).

This guidance document indicates that buffers should be planned and installed in accordance with NRCS practice standards and criteria. Where available, state standards and criteria should be used. This document also indicates that, with some limits, buffers can be installed at widths exceeding the minimum standard to meet landowner and multiple conservation objectives. These limits are established to ensure that the intent of the continuous sign-up provision of CRP is followed.

This flexibility is designed to accommodate multiple landowner objectives. A filter strip, for example, is intended to improve water quality first and foremost, but landowners can enhance the wildlife habitat and other environmental values within filter strips by increasing the width of the strips and by using plant materials that are particularly suitable for target wildlife species. Maintenance, such as mowing and weed control, should be planned to protect the habitat and other values provided by the buffer. Whenever possible, groups of adjoining landowners should be encouraged to plan and install conservation buffers on a landscape scale--across multiple land units.

Buffer practices are most effective in protecting and enhancing natural resources when they are combined with other appropriate conservation practices, such as conservation tillage, crop residue management, nutrient management, and integrated pest management, and establishment of plants that benefit target wildlife species. The National Conservation Buffer Initiative provides the opportunity for landowners to develop and implement comprehensive farm conservation plans. Conservation buffers also can be used to help many communities accomplish large-area or watershed-level goals and objectives. Buffers are common-sense conservation.

A nparison of conservation purposes and practices listed ir e CRP rule (February 19, 1997), applicable NRCS conservation buffer practices, and suggestions on program implementation. All CRP rule references are to Section 1410.6.

Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
General	Seeding and Maintenance	CRP seeding and maintenance recommendations should be followed in planning and installing conservation buffers as part of the continuous CRP sign-up. In addition, maintenance required to insure the proper functioning of conservation buffers should be included as part of the conservation plan and CRP contract. Guidance on seeding and maintenance are contained in individual practice standards.
	Landscape or Watershed Approach	Whenever possible, adjoining landowners should be encouraged to plan and install filter strips, riparian buffers, and other conservation buffers at the landscape or watershed scale.

A comparison of conservation purposes and practices listed in the CRP rule (February 19, 1997), applicable NRCS conservation buffer practices, and suggestions on program implementation. All CRP rule references are to Section 1410.6.

Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
Filter Strip and Riparian Buffer	Filter Strip (393) and Riparian Forest Buffer (391) with or without Streambank and Shoreline Protection)	These practices should be installed adjacent to steams, other permanent waterbodies (such as a lake or pond), wetlands, and sinkholes. The primary objective of these practices is to protect streams, other waterbodies, and wetlands from pollutants--sediment, other suspended materials, and dissolved chemicals. These practices also enhance wildlife habitat. A **filter strip** is planted to close-growing, stiff-stemmed grasses that will dissipate the energy of flowing water and grow under environmental conditions, such as a high salt content. Filter strips help slow runoff, intercept and spread concentrated flow, enhance infiltration of water and assimilation of dissolved chemicals, and trap sediment and other suspended material. If a primary purpose of a filter strip is to trap and remove nutrients and other chemical pollutants through uptake by plants, periodic maintenance should be planned. The minimum acceptable width of a filter strip is 20 feet. A **riparian forest buffer** is planted to tree, shrub, and herbaceous species that can absorb nutrients and other chemicals carried into the buffer area by surface or subsurface water. The high organic matter resulting from leaf fall from the trees and the dense root systems create an environment at the soil surface that encourages biological degradation and recycling of chemical compounds. The woody roots of the trees and shrubs, and branches that fall along the bank or shore, help reduce streambank or shoreline erosion. The trees in a "managed forest" part of the buffer should be periodically harvested to remove stored nutrients and encourage vigorous growth and reproduction of the remaining plants. Commercial tree harvest is not permitted during the term of a CRP contract, however. The minimum combined width of zones 1 and 2 in a riparian forest buffer is 100 feet or 30 percent of the geomorphic floodplain, whichever is less, but not less than 35 feet. A filter strip should be added, if

Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
		appropriate, as zone 3 of a riparian forest buffer. The filter strip and riparian forest buffer practices, along with streambank and shoreline protection, may need to be applied as a system to provide full protection to water quality and to meet landowner objectives. Minimum standards for these practices depend on upland and riparian soil types, percent slope and slope lengths, and conservation practices applied on land above the buffers. Practices should always be installed to meet the minimum standards to control the identified water pollution problem, but they may exceed minimum standards to meet landowner objectives. **For purposes of the CRP continuous sign-up, the filter strip can be applied up to a maximum average width of 100 feet, except in those cases where the minimum design specification exceeds 100 feet, in which case the minimum design specification becomes the maximum average width that can be enrolled; the riparian forest buffer (zones 1 and 2 combined) can be applied up to a maximum average width of 150 feet, except in those cases where the minimum design specification exceeds 150 feet, in which case the minimum design specification becomes the maximum average width that can be enrolled.** This means the width of filter strips and riparian forest buffers may be adjusted to allow a landowner to square a field or straighten rows adjacent to the buffer. At no point, however, can the narrowest portion of a filter strip or riparian forest buffer be less than the minimum width recommended.

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Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
Contour Grass Strip	Contour Buffer Strip (332) and Associated Field Borders	This practice includes multiple strips of permanent vegetation planted in a cropland field to reduce sheet and rill erosion, reduce transport of sediment and other water-borne pollutants downslope, and enhance wildlife habitat. A contour buffer strip is normally planted to close-growing, stiff-stemmed grasses that will dissipate the energy of flowing water so that sediments and other pollutants are captured in the buffer. The outlet of a contour buffer and the associated ends of furrows where water will drain from the field should be planted to permanent vegetation capable of protecting the soil from erosion and capturing any pollutants that may drain from the field. These end-row or field border areas are eligible for enrollment in the continuous CRP sign-up as long as they are integral components of a field buffer system that includes contour buffer strips. Minimum standards for the width of a contour buffer strip and the number of strips needed in a field will depend on soil types, percent slope and slope lengths, and conservation practices applied on the field. The lower most contour buffer strip in a field may be two (2) times the minimum width recommended for the practice. The minimum acceptable width for a contour buffer strip designed for soil erosion control purposes is 15 feet, while the minimum acceptable width for a contour buffer strip intended to enhance wildlife habitat is 30 feet. The minimum acceptable width for a contour buffer strip seeded to grass or a grass/legume mixture is 15 feet. The minimum acceptable width for a contour buffer strip seeded to legumes is 30 feet; legumes are unlikely to persist for the duration of a CRP contract, however, so reseeding may become necessary unless native plants naturally replace the legumes over time. Contour buffer strips should always be installed to meet the minimum standards to control the identified water pollution problem, but they may exceed minimum standards to meet other landowner objectives. **For purposes of the CRP continuous sign-up, a contour buffer strip up to 30 feet wide can be installed, except in those cases where the minimum design specification exceeds 30 feet, in which case the minimum design specification becomes the maximum width; the**

Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
		lower most contour buffer strip in a field can be a maximum of 60 feet wide.

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Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
Grass waterway	Grass waterway (412)	This practice consists of a natural or constructed channel designed to convey water off of a field without causing erosion. Grassed waterways should be installed within or at the ends of fields where natural drainage patterns exist and uncontrolled concentrated flow will cause gully erosion. The waterway channel may be graded or shaped to facilitate water flow. The waterway should be planted to grasses that will protect the waterway from erosion. During flow events, the grass in the waterway, along with the designed gradient, helps to retard the flow of water, reducing the potential for erosion and facilitating the safe release of water at the outlet. Woody plantings may be appropriate on channel back slopes to improve screening, wildlife habitat, space definition, and climate control. Some sediment and other pollutants may be captured in the waterway if water flow is slow, but most runoff and water-borne pollutants will be conveyed off of the field as water flows through the waterway. It is important that the waterway deliver water through a stable outlet to a filter strip, riparian forest buffer, waterspreading system, constructed wetland, or other appropriate area if the water is likely to contain a high load of sediment, other suspended materials, or dissolved pollutants. If the water from a grassed waterway will be free of pollutants, the water can be released to a stream or other water body through a stable outlet. Minimum standards for a grassed waterway are based on the peak runoff volume for the 10-year, 24-hour storm event and its gradient, soil, and vegetation. Grassed waterways should always be installed to meet the minimum criteria to convey water off of the field, with appropriate complementary practices installed to control any pollutants likely to be in the water. Once vegetation is established, waterways should be maintained to ensure that runoff does not flow along the edge of a grassed

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Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
		waterway, causing a gully. **For purposes of the CRP continuous sign-up and to meet landowner objectives, grassed waterways can be constructed up to a width of two (2) times the minimum design standard specified, but in no case can a grass waterway exceed a maximum width of 100 feet.** Use of grassed waterways by farm equipment, livestock, or wildlife should be carefully managed to ensure that the water conveyance purpose of the waterway is protected.

A comparison of conservation purposes and practices listed in the CRP rule (February 19, 1997), applicable NRCS conservation buffer practices, and suggestions on program implementation. All CRP rule references are to Section 1410.6.

Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
Field Windbreak and Shelterbelt	Windbreak / Shelterbelt Establishment (380)	These practices modify wind to reduce wind erosion, protect growing plants, provide shelter for buildings and livestock, and cause planned deposition of the wind-blown materials. They can also provide living screens, wildlife habitat, and landscape diversity. These practices consist of single or multiple rows of trees and shrubs planted perpendicular to the prevailing wind. The distance sheltered by the barrier shall be 10 times the height of the tallest plants in the buffer, with the greatest effect occurring at 3-7 times the height of the tallest plants. If the primary purpose of the buffer vegetation is to protect fields from wind erosion and crops from wind damage, then several strips of vegetation will need to be planted in the field, each at approximately 10 times the height of the plants from the upwind strip. If the primary purpose of the buffer vegetation is to protect buildings, stationary equipment, roads and other property from wind-borne material, one or more strips should be planted upwind of the properly to be protected The arrangement of the strip and distance of the strip from the property to be protected should be planned so wind-borne materials are deposited so they do not damage the property. While individual buffer practices can treat localized problems, developing a buffer system that prevents wind damage is recommended as the best way to protect property from wind-borne sediment. If the primary purposes of the vegetation is to reduce the discomfort caused by wind to humans, livestock, and wild animals, the vegetation should be planted to shelter the areas to be protected on at least two sides. Practices should always be installed to meet the minimum criteria to control the identified wind-related problem. **For purposes of the CRP continuous sign-up and to**

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		meet landowner objectives, field windbreaks for wind erosion control should be installed to the design standard, while shelterbelts to protect building, roads, and other property can be installed at a width up to two (2) times the design standard. Practices to manage the effects of wind should be designed and applied at the landscape scale whenever possible.

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Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
Living Snow Fence	Windbreak / Shelterbelt Establishment (380)	When used as living snow fences, the purpose of these tree, shrub, or grass strip practices is to manage the deposition of blowing snow to protect buildings, roads, and other property; provide shelter for livestock and wildlife; and collect snow to enhance water supplies. Site-specific design requirements, including the height and density of the vegetation, must be followed to successfully manage the accumulation of snow.

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Practices or Purposes Listed in CRP Rule	Applicable NRCS Buffer Practice Standards	Suggestions on Program Implementation
Saline Areas and Well Head Protection Areas	Filter Strip (393) or Riparian Forest Buffer (391)	Many of the problems identified in the CRP rule do not conform to a shape implied by conservation buffer "strip." Establishing permanent vegetation on these areas is critically important, however. The chosen practice should conform to the shape of the problem, and plants should be chosen that are compatible with the environmental conditions present on the site. For the purpose of the CRP continuous sign-up, the following areas are eligible for enrollment in the program: **Well Head Protection Areas**--Land within a maximum 2,000-foot radius from a public well, as designated by the Environmental Protection Agency or a state-designated agency can be enrolled. Circular shapes can be squared off to eliminate odd-shaped corners for a maximum of 367 acres. **Saline Areas**--The affected discharge area should be planted to vegetation capable of growing in the saline environment and capable of reducing the saline seep. Based on state and local guidance, this area can be increased minimally, as needed, to fully protect natural resource values and to meet landowner objectives.